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MEMOIRS OF THE DEPARTMENT OF AGRICULTURE IN INDIA

ERI SILK

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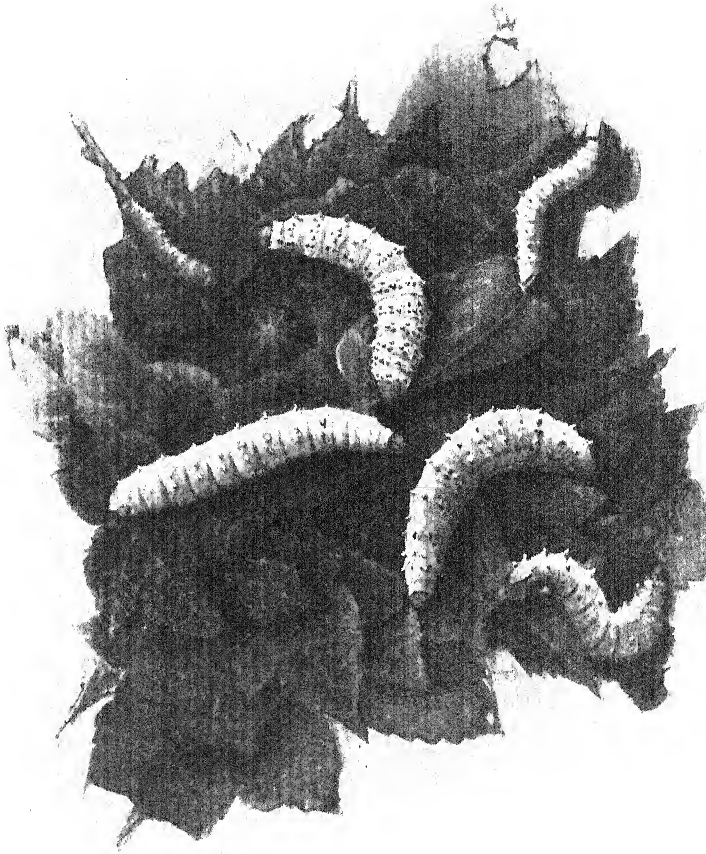

ERI WORMS.

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I. INTRODUCTION.

Eri silk is a silk grown in Assam for local use, the fibre being spun, woven and worn by those who grow it. It is known as "Endi" and the woven cloth as "Endi" cloth. It is also exported to Europe for forming spun silk, with the waste silk left after reeling mulberry, tasar and other "reeled" silks. The silk differs from other silks in that it cannot be reeled, *i.e.*, a single continuous thread cannot be obtained from one cocoon as is done in mulberry silk; the cocoon actually is not formed of a long continuous thread as in mulberry silk, but is spun by the worm in layers; it differs also from these silk cocoons in that it is so made that the moth can push its way through one end without softening or cutting the fibres, this end not being really closed but being so blocked with loops of silk that nothing can get in, but the moth, pushing from within, can force its way out.

The silk has also this peculiarity that to get it the cocoons need not be steamed to kill the insect within, as must be done with mulberry or tasar silk; the moth may be allowed to mature inside the

cocoon and emerge; this removes one of the objections to mulberry silk, in that no life need be taken before the silk can be obtained.

Eri silk will probably be extended to other parts of India which have a suitable climate, not for cultivation on a large scale so much as on a small scale without special appliances or buildings; the fibre can be spun as cotton is, the yarn can be woven quite readily and the silk cloth produced is the most durable cloth known in India, far more so than cotton. It takes dyes well, the ordinary plant-dyes of this country being more suited to silk than to cotton.

It remains to be seen whether it will be profitable to take it up on a large scale for sale in India or Europe; the sole disadvantage is the immense amount of space required for rearing the worms, and we do not at present advise anyone to take it up on a large scale unless the spinning and weaving can also be taken up with it and finished cloth produced. There is at present a demand for cocoons, but this might be met by its increased production on a small scale and a large production of cocoons to be sold as cocoons might not be profitable at once.

In these pages the methods found best at Pusa for cultivation on a small scale are described; further information, and eggs or cocoons can be obtained on application to Pusa; if a large quantity of eggs is required to commence cultivation, it is necessary to give notice, as eggs cannot be kept for more than ten days and are not always being laid.

II. REARING.

I. Instructions.—The following are short instructions for rearing which give a general account of the process. Following this are more detailed notes on rearing and a full account of the rearing at Pusa.

The insect exists in four stages, the egg, worm, chrysalis and moth. The moths lay eggs, which hatch to worms which feed on castor leaves till they are full grown when they spin cocoons and from these cocoons moths come out. The following are instructions for rearing.

Eggs are obtained and kept in any vessel to which air can get ; we keep them in a tray. In very dry hot weather, as when the West wind blows, cover the trays with a damp cloth, better still with a wet gunny cloth. In very cold weather, cover the tray similarly and place it thus covered in the sun during the day, always taking care that the covering cloth does not get dry ; at night no covering is necessary. The eggs are white ; when they turn grey, they are going to hatch. They must then be spread out evenly and the smallest leaves of castor spread over them ; as the worms hatch, they crawl on to the leaves and these leaves can be lifted up and placed in the feeding tray. In hot weather, eggs hatch in seven days ; in cold weather, they may stay as long as 24 days.

When the worms hatch, transfer them to feeding trays ; feed on the small leaves of castor twice a day. Very great care must be taken of young worms ; they must not be mixed with older ones ; all that hatch on the same day must be kept together. The leaves must not be chopped up but each should be torn into two or three pieces. In dry weather, the leaf dries and the worms should be given fresh leaves three or four times a day ; the trays may be covered with wet cloth in order to prevent the leaves drying up soon. In very cold weather, keep the young worms in the sun in the same way as eggs, covered with wet cloth. Worms must never be handled more than absolutely necessary, and that very gently ; each day after they have been given fresh leaves, lift them on the leaves to a fresh tray and, when all are moved, clean the tray.

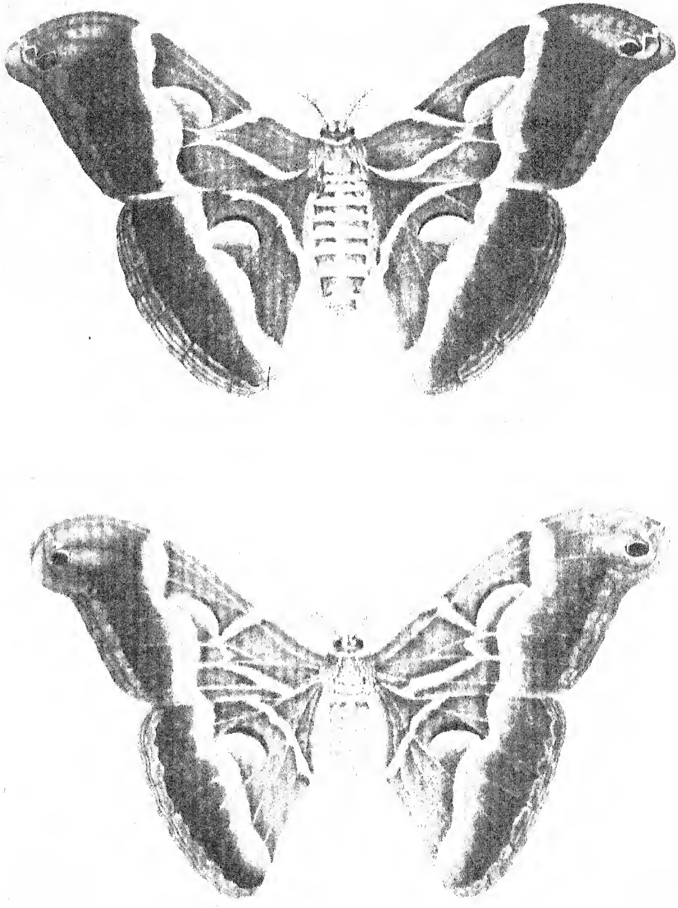
After a few days the worms stop feeding and look sick ; they are now going to moult and must be left alone ; as they finish moulting and become well, they become restless and want food. Some die at this moult. Continue feeding as before, only feeding also once at nightfall and giving bigger leaves ; in a few days they will again moult. Continue as before and after the next moult (third) feed four times daily, once at night. In hot weather, feed oftener if the worms are restless or the leaf dries up. After the fourth moult, the worms are in the last stage and want feeding five or six times a day, once or twice

at night. If the food is not enough, they will become restless and move about. Never feed worms that are moulting. Keep worms of one age or size together and do not mix them with others. The worms should not be kept overcrowded. Leaves must not be dusty or wet; the leaf given is to be without the leafstalk. There are two kinds of worms, some are black-spotted and others are without black spots. Of both kinds, in the advanced stages, some remain white and others develop a green colour. When the full-grown worms stop feeding and move about, they want to spin. They do this between 9 and 12 o'clock in the morning and one must be ready then to put them away to spin. White worms turn yellow when they are ready to spin; another way of telling if worms are ready to spin is to hold each in the fingers near the ear and pass the fingers along the fleshy spines; a worm ready to spin makes a hollow sound, a worm not ready a dull sound. When the worms get ready for spinning, they deposit a large quantity of excrement and then crawl to the edge of the tray; collect them then, when they are on the edge of the tray and place them in spinning baskets. The baskets must be ventilated, the best are ordinary fruit baskets, loosely woven. Put on the bottom of the basket a layer of crumpled paper, or chips of dry straw or dry leaves; on this put the worms; then add more material and put in more worms. When the basket is full, put on the lid and see that there is no empty space below it. Put a weight on the lid or turn the basket over. About 500 worms can be put into a basket $1\frac{1}{2}$ feet in diameter; do not overcrowd the worms. After five days in hot weather, or eight days in cold weather, pick out all the cocoons from the basket and spread out evenly on trays. The cocoons are white or brown. By always taking eggs from moths from white cocoons, all the cocoons will come white; so keep the brown cocoons on one side and do not let their moths' eggs be reared. After the cocoons have been spread out from ten days in summer to a much longer period up to forty days or more in winter, moths come out. Let them alone for some hours, then go round with an empty basket [the spinning basket serves the purpose] and put them on the sides, inside. The

PLATE II.

Picking out Cocoons.

PLATE III.



Eri Moths.

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females (which have large bodies) and the males (which have small bodies) are to be placed side by side. They will sit on the sides of the basket; cover the baskets. The next day pick out all the unpairing moths from the basket and leave the pairing couples alone till the day after; then pick out all the females by separating them from the males if they are still coupling and put them in a separate basket; the males may be thrown away. The females will lay eggs there; scrape off the eggs by means of a blunt knife or stick and keep them for hatching; the best eggs are laid the first night, usually about eighty by each female on the average; so if these are sufficient, do not rear the later eggs; but if many eggs are required, keep those laid on the first three nights. The moths do not fly away and want no food. A moth will lay 200 eggs as a rule; so that if you start with 100 eggs and rear these, you should get 90 moths, of which perhaps forty will lay eggs, laying in all some 8,000 eggs; these moths will lay some 600,000 eggs. Be careful not to rear more eggs than you can feed.

Use of Cocoons.—After the moths have all come out, pick over the cocoons and get off any straw, etc. Then boil them in water; use about $2\frac{1}{2}$ gallons of water (a little more than half of a kerosine tin or about 10 litres), half of a seer (1℔) of cocoons and 2 chittacks (4 oz.) of washing soda. It is best to first soak the cocoons in water for 18 hours; then wash them well in enough water by squeezing them with the hands until all the dirt is removed; boil the soda in fresh water ($2\frac{1}{2}$ gallons) and tie up the cocoons in a cloth and drop this bundle into the boiling water and soda and keep the bundle submerged in the boiling water by placing a brick or any heavy thing. Boil for three-quarters of an hour. Then lift the bundle out and keep the liquid left for dyeing if any dyeing is being done. Wash the whole bundle without untying it in enough water until no longer any dirty water comes out of the cocoons. Now squeeze the water out of the bundle. These cocoons can then be dyed or be spun direct. If the spinning is done with the spindle (taku) or the Continuous Spinning Machine, use wet cocoons. If, however, the country spinning wheel (charka) is used, dry the cocoons thoroughly and spin from the dry cocoons. Dry

cocoons can be carded out and spun like wool; but it is better to spin direct from cocoons. A seer of cocoons gives 10 to 12 chittacks of thread, *i.e.*, $\frac{5}{8}$—$\frac{3}{4}$ of the cocoons form thread.

The following are some general principles :—

(1). Try to have always going, some young worms, old worms and cocoons, *i.e.*, do not have all the worms the same age, or at one time you will have a lot of work, later you will have very little.

(2). The same people who rear should do boiling and spinning so as to have work always.

(3). Try to get fresh eggs every year and exchange eggs.

(4). In the hot weather when the dry winds blow, keep out dust, keep the place cool and moist, and feed often and little; do not give large quantities of leaf which dries up.

(5). Have the castor as near to the rearing house as possible.

(6). Rear only small broods in April, May, large ones in June, July, August, September, October and on till February.

(7). If there is a choice, rear from the largest and best cocoons.

(8). Cocoons get small in the dry hot weather: that does not matter; rear from the best.

(9). Good cocoons weigh 2,500 to the seer after the moth has emerged, small ones 3,500 to 4,000.

(10). Seventy-five seers of leaf feed sufficient worms to yield a seer of cocoons.

The following are the instructions given to the rearers in the silkworm house :—

I. Two principal things :

(1). To feed with the best leaves available.

(2). To keep the worms as clean as possible, free from refuse and excrements. To see that they are no in case overcrowded.

II. To weigh:

(*a*) the leaves supplied;

(*b*) the leaves thrown out by the worms, *i.e.*, wastage;

(*c*) the excrements thrown out.

PLATE IV.

III. Not to handle the worms too much.

IV. To see that the worms do not drop down on the ground; if they do, they are to be instantly picked up and placed on the feeding baskets.

V. If any die, the dead ones should be at once taken out and put into the fire.

VI. To count how many die every day.

VII. Always to pay attention while cleaning first to those trays in which the worms seem to be most uncleanly or overcrowded.

VIII. Not to let the worms spin in the feeding trays. If any cocoons are spun in the trays, they are to be taken out when seen.

IX. To keep the cocoons clean.

X. To take a turn round the whole house every half hour, keeping the eye watchful to find out:

(1) if any worms have dropped down;
(2) if any have gone down the baskets;
(3) if any have died;
(4) if any are straying about;
(5) if any want to spin;
(6) whether leaves are to be supplied to any tray.

XI. As rats destroy cocoons and worms at night, the cocoons are always to be kept in closed tight baskets into which rats cannot enter. It cannot be helped for the worms, as they are to be fed in open trays.

2. *The Rearing House and Appliances.*—The rearing house at Pusa (Plate IV) is constructed of bamboos and thatching grass, in the usual way, with a row of sissu trunks in the centre as posts since the width of the building is considerable. The construction of the sides allows of ample ventilation. The upper portions of the side walls are so made that they can be lifted up or shut down as desired. There are no special features about the house and a rearing house requires only to be so built as to contain the greatest possible amount of space for trays. The nature of the house and its arrangement vary according to locality and climate; too much ventilation in a cold climate, which lets the temperature fall below

55° F. at night, is bad; so also in dry hot weather; for many places mud walls and a thatch or tile roof are best. Mud-walled thatched houses have this advantage that they are cool in summer and warm in winter. The question depends mainly on local conditions and no general recommendations can be made. It is important to keep the floor of the house as clean and free from dust as possible, especially in view of disease. With an earth floor such as we have, constant wetting is necessary to keep down dust, and this helps to keep the house cool and moist in hot weather. For the same reason if any choice can be made, rearing houses should be as far removed from dusty places or roads as possible.

In the rearing house at Pusa a framework of split bamboo is built up in the middle and at each side, as illustrated (Fig. 1);

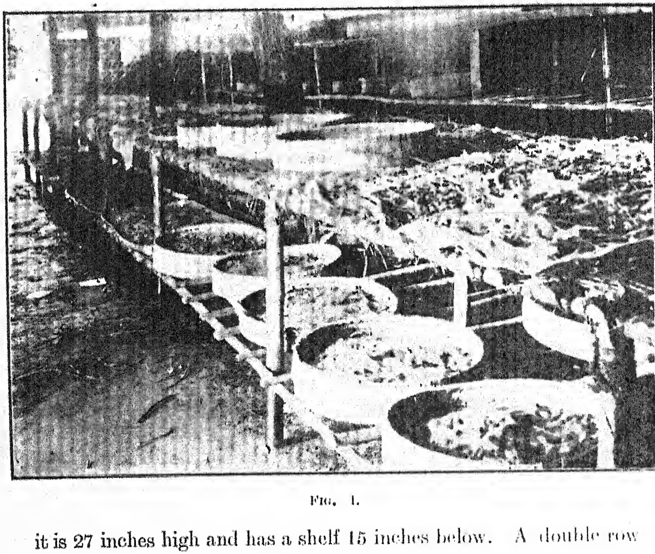


FIG. 1.

it is 27 inches high and has a shelf 15 inches below. A double row of trays can be accommodated.

When the rearing of Eri silk worms is taken up as a small subsidiary industry by a cultivator, he need not build any special rearing house. He can use a corner of any available house and in order to accommodate the trays in the smallest possible space, a machan of the kind shown in Fig. 2 can be built. This

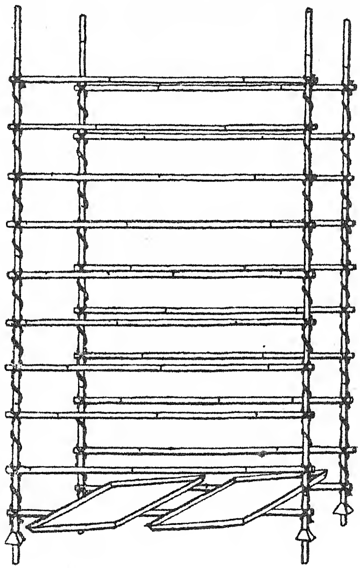


FIG. 2.

machan is formed by fixing two pairs of upright posts in the ground and tying crossbars horizontally. The pairs of parallel crossbars at the same level form shelves. When no rearing is done, the machan can be easily dismantled and kept aside.

Rearing appliances include trays and baskets only. We used in the beginning the small close-mesh trays (Fig. 3) for eggs and young worms. As the worms grew larger, open-mesh trays were used (Fig. 4); these had a raised bottom so that much of the excreta dropped down and they remained more or less clean. Occasionally the tray shown in Fig. 5 was used when the worms were about to spin; it is an ordinary open-mesh tray with an extra space all round which is filled with straw or waste paper or any spinning medium, and as each worm becomes full-grown, it crawls in and spins without requiring separate attention.

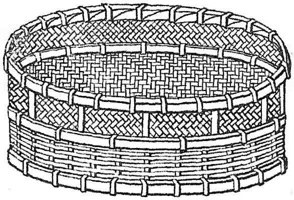


FIG. 3.

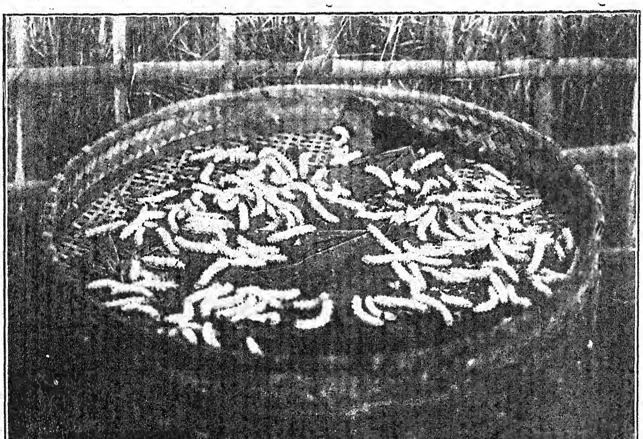


FIG. 4.

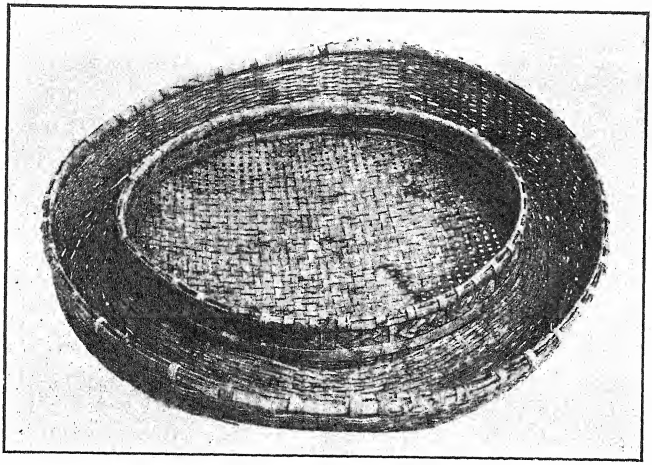


FIG. 5.

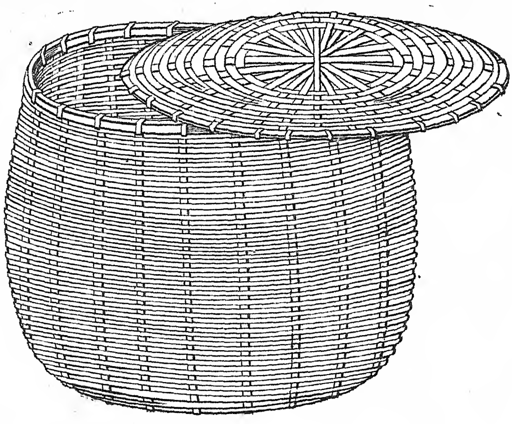


FIG. 6.

The trays with holes are disadvantageous in this way that when they are placed one over another on the shelves, mats must be used between them or the excrements of the worms above drop on the worms below. If a little care is taken in cleaning, the worms in all stages can be as well kept in trays without any holes. Covered baskets (Fig. 6), such as are used for fruit, are required for cocoons and moths. The emergence tray shown in Fig. 7 is the only

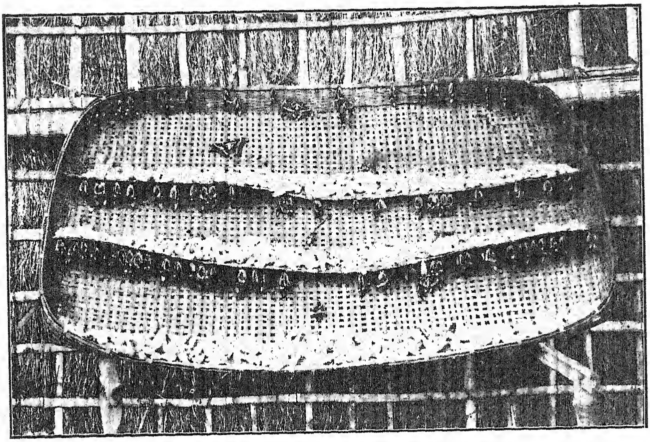


Fig. 7.

new feature; it is placed at an angle and the cocoons spread out; the moths as they emerge crawl up to the lower side of the cross partition, where they hang till the wings expand. They also void their excrement on the tray, not on the cocoons and the pierced cocoons are cleaner.

We now use only trays with completely closed meshes, either square or oblong and of a size which is easy to handle. These are

really small mats with their edges turned up (Fig. 8). These trays can be very conveniently used for making the worms spin cocoons with

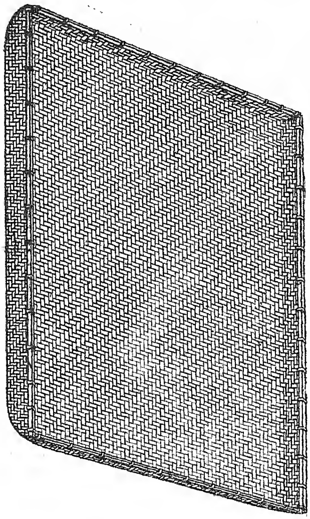


FIG. 8.

the spinning medium, straw, dry leaves, etc., spread on them. For rearing therefore are necessary, a number of these trays which can be used both for feeding the worms and making them spin cocoons, a few small trays (Fig. 3), for eggs and a few covered baskets (Fig. 4), for taking eggs from moths. The eggs can be kept on feeding trays and the small trays can be dispensed with ; but the latter are convenient when eggs are to be covered with wet cloth in the hot season.

The trays can be made of any cheap material available in any locality. We use bamboo. In the United Provinces a weed locally known as *sirki* is very plentiful, and trays, etc., are made of this and sold very cheap. A little modification in the make so as to have the sides not so high as usually made, would fit them admirably for silkworms.

For rearing on a large scale, the use of trays is unnecessary and costly; they are used only for the eggs to hatch and for the young worms. A few of the small round trays may be used and a few larger rectangular trays. For the worms after the first moult, plain pieces of mat are used and the worms can be handled easily, kept well spaced out and readily cleaned and fed. So also for spinning, the enormous mass of baskets required on a large scale and the great amount of material is difficult to maintain; it is best to let the worms spin in a deep layer of dry mango leaves spread out on a machan or floor, mango leaves being the best material yet found on account of the shape of the dry leaf offering convenient cavities for the worms.

Coupling.

I. Experiments to determine the best period of coupling and the number of eggs laid :—

(1). Moth emerged 16th November was kept separate and not fertilised.

She laid eggs as follows:—

6	eggs on night of	19th	November.
12	,, ,, ,, ,,	20th	,,
12	,, ,, ,, ,,	21st	,,
27	,, ,, ,, ,,	22nd	,,
43	,, ,, ,, ,,	23rd	,,
53	,, ,, ,, ,,	24th	,,
35	,, ,, ,, ,,	25th	,,
45	,, ,, ,, ,,	26th	,,
40	,, ,, ,, ,,	27th	,,
Total 273			

She died on 3rd December.

The eggs did not hatch.

(2). Moth emerged 8 A.M., 14th November.

Coupled 1 hour, between 9 & 10 A.M., 15th November.

She laid eggs as follows :—

6	eggs on night of	15th	November.
8	,, ,, ,, ,,	16th	,,
16	,, ,, ,, ,,	17th	,,
Carried over 30			

Brought forward	30						
	21	eggs	on	night	of	18th	November.
	17	,,	,,	,,	,,	19th	,,
	30	,,	,,	,,	,,	20th	,,
	33	,,	,,	,,	,,	21st	,,
	73	,,	,,	,,	,,	22nd	,,
TOTAL	204						

Only 8 eggs became grey, none hatched.

(3). Moth emerged 8 A.M., 14th November.

Coupled 9—11 A.M., 15th November, *i.e.*, for 2 hours.

She laid eggs as follows :—

	8	laid	on	night	of	15th	November.	5	turned	grey.
	9	,,	,,	,,	,,	16th	,,	2	,,	,,
	8	,,	,,	,,	,,	17th	,,	1	,,	,,
	20	,,	,,	,,	,,	18th	,,	3	,,	,,
	48	,,	,,	,,	,,	19th	,,	11	,,	,,
	75	,,	,,	,,	,,	20th.	,,	15	,,	,,
TOTAL	168									

None hatched. She died 21st November.

(4). Moth emerged 8 A.M., 14th November.

Coupled 9—12 A.M., 15th November, *i.e.*, for 3 hours.

She laid eggs as follows :—

	3	eggs	laid	on	night	of	15th November.
	13	,,	,,	,,	,,	,,	16th ,,
	29	,,	,,	,,	,,	,,	17th ,,
	21	,,	,,	,,	,,	,,	18th ,,
	41	,,	,,	,,	,,	,,	19th ,,
	17	,,	,,	,,	,,	,,	20th ,,
TOTAL	124						

Of these only 4 turned grey. None hatched. She died 21st November.

(5). Moth emerged 8 A.M., 14th November.

Moth coupled 9 A.M. to 3 P.M. 15th November, *i.e.*, for 6 hours.

Eggs laid as follows :—

No.	Date.	Weight per 100.	Hatched.	Number not hatched.
65	15th Nov.	2·84 grains.	30-11	
38	16th Nov.	2·76 ,,	30-11	
27	17th Nov.	2·64 ,,	23-12	
20	18th Nov.	2·50 ,,	5-12	2
19	19th Nov.	2·40 ,,	6-12	3
11	20th Nov.	2·40 ,,	7-12	1
26	21st Nov.	2·00 ,,	8-12	6
7	22nd Nov.	2·00 ,,	..	6
213				

Moth died, 29th November.

(6). Moth emerged 8 A.M., 14th November.

Moth coupled 3 P.M. of 15-XI to 7 A.M. of 16-XI.

Eggs laid :—

1	16th November.			
6	17th ,,	6 turned grey.		
14	18th ,,	4	,,	,,
19	19th ,,	19	,,	,,
34	20th ,,	34	,,	,,
29	21st ,,	29	,,	,,
28	22nd ,,	28	,,	,,
32	23rd ,,	32	,,	,,
27	24th ,,	7	,,	,,
3	25th ,,	none	,,	,,
193				

She died, 29-XI. None hatched.

(7). Moth emerged noon of 13th November.

Moth coupled 6 P.M. of 13-XI to 6 P.M. of 14-XI.

73 eggs laid on night of 14-XI, which weighed 3·4 grains per 100, and hatched 28 and 29-XI.

Was coupling on morning of 15-XI. 9 eggs laid night of 15-XI, which weighed 2·9 grains per 100, and hatched on 29-XI.

Was coupling on morning of 16-XI. 141 eggs laid night of 16-XI, weighing 2·9 grains per 100, hatched on 1-XII.

Was coupling on morning of 17-XI and was separated at 9 A.M., 98 eggs laid night of 17-XI, weighing 2·72 grains per 100, which hatched on 2nd—4th December.

21 eggs laid night of 18-XI, weighing 2·5 grains per 100, hatched on 5-XII.

19 eggs laid night of 19-XI, weighing 2·4 grains per 100, hatched 7-XII.

9 eggs laid night of 20-XI, weighing 2·3 grains per 100, hatched on 7-XII.

7 eggs laid night of 21-XI, hatched on 9-XII.

One egg laid, 22-XI, hatched on 9-XII.

Total, 378 eggs. Moth died, 23-XI.

In the following three cases, copulation ran its full course, the pairs being isolated but not separated :

(8). Emerged, 25th March.
Coupled night of 25th March to morning of 27th March.
235 eggs laid night of 27th March.
Were coupling on morning of 28th March.
Ceased coupling and laid 101 eggs, night of 28th March.
49 eggs laid night of 29th March, and the male died.
20 eggs laid night of 30th March.
10 eggs laid night of 31st March.
Female died, 1st April.
415 eggs laid, which hatched.

(9). Emerged, 25th March.
Commenced coupling night of 25th March.
27 eggs laid night of 26th March.
The couple separated on 27th March.
15 eggs laid during day of 27th March.
14 eggs laid during night of 27th March.
Coupled again, 28th March.
17 eggs laid night of 28th March.
Ceased to pair, morning of 30th March.
Male died, 30th March.
5 eggs laid night of 31st March.
Female died, 1st April.
188 eggs laid, which hatched.

(10). Emerged, 25th March.
Coupled, 25th March.
25 eggs laid night of 27th March.
Were still found coupling morning of 28th March.
Ceased to pair and laid 247 eggs, night of 28th March.
59 eggs laid night of 29th March.
Male died night of 29th March.
17 eggs laid night of 30th March.
6 eggs laid night of 31st March.
Female died, 1st April.
Total, 354 eggs laid.

In the above cases, the number of eggs varies from 124 to 415; the coupling should occupy 24 hours to be effective and the best eggs are laid on the first night, after separation; eggs are laid in spite of continued coupling. Unless separated, coupling continues for about 72 hours, and males in some cases died coupling. Pairs isolated and separated after 30 hours coupling, coupled again and the eggs laid hatched. The best practice is to allow coupling for 24 hours, and, unless a large increase is required, to keep for hatching only the eggs of the first night's laying. On 6th November, 250 female moths that emerged were allowed to couple and were separated on 8th November; they laid 21,800 eggs that night, giving an average of a little over 80 eggs each for the first night's laying, which the above tables show to be heavy eggs.

4. The Eggs.

Moths lay eggs wherever they are sitting, in a cluster which may contain as much as 100 or more; each egg is coated with gum which dries, fastening the eggs firmly together and as the moth moves little, the eggs are often built up as a little curved wall behind her, projecting out at right angles to the surface she is resting on. The eggs are white, but the gum gives them a yellow look; they are oval in outline, and with a very tough smooth shell. In moist warm weather they hatch in seven to nine days; exposed to the dry heat of the west winds in March, they required some days more, eleven to twelve days in all. Moisture is a necessity for prompt

hatching, possibly because of the amount absorbed in the development of the embryo before it can emerge.

Eggs should never be kept in air-tight vessels or boxes. In Assam, eggs are kept tied in a piece of cloth and hanging from eaves, etc. Sometimes water is sprinkled on the eggs; dipping in water does them no harm—$\frac{1}{2}\%$ solution of blue-stone (Copper Sulphate) is salutary. We have even used 1% solution of blue-stone without any injury. Eggs are put in a piece of cloth which is dipped in the solution until the eggs are thoroughly wet. The water is then jerked out as much as possible and the eggs spread to dry in the shade. In summer, the rains and in early winter, the eggs do not require any special moist surroundings. In very cold weather they keep well and hatch uniformly if kept in a moist and at the same time warm condition. This is brought about by covering the tray in which they are kept with a wet cloth and placing the tray thus covered in the sun, always taking care that the cloth does not get dry. When the dry west winds blow, they are to be put in slightly moist surroundings. They keep well if they are kept covered with a moist cloth. If the eggs are kept in a castor leaf or any other big fresh leaf and the leaf itself tied in a piece of cloth and kept in a cool place, the eggs keep well; the leaf has to be changed when dry. Moist leaf is favourable to the worm in all its stages.

The best method of taking eggs from the moths is in covered baskets (Fig. 6). For this purpose the baskets in which the worms are made to spin cocoons may be very conveniently used. As the moths emerge they are picked out and placed inside the basket; they are made to hang on the sides and never placed on the bottom. Female moths will hardly stir from the place where they are put. Males flutter about at nightfall. A male and a female are put together almost touching each other or the male may be made to hang on the body of the female. The moths are to be put in this way before it is evening. Next morning most of the pairs will be found to be coupling. The single unpairing moths are now removed from the basket. Twenty-four hours copulation is enough for the fertilisation of the eggs. Practically we have found the following method to

be very good :—Moths which couple to-night are allowed to mate for to-night, to-morrow day and night, the day after to-morrow till about 2 or 3 P.M., when the males are forcibly separated and thrown away, the females are kept in a clean basket and lay eggs at night ; on this night on an average each female will lay about 80 eggs. If a large number of females is available, it is better to take only the eggs of the first night and then reject the females. At any rate, if more females are not available, eggs of only the first three nights should be taken and the females rejected. (The eggs of subsequent nights become gradually smaller and weigh less.) Some couples will be found to have separated after 24 hours' copulation and the females to have laid eggs. (Paired this evening and separated and laid eggs to-morrow night.) These eggs should be taken as they are quite healthy and fertile. Other methods of taking eggs, *e.g.*, by tying the moths to reeds, etc., are unsatisfactory.

Eggs turn grey before hatching. Eggs laid on the same night should be kept together and separately from those of other days. Eggs of the same day will turn grey at the same time ; if among them any eggs are found not to have turned grey they should be picked out and rejected, usually they fail to hatch, and if they hatch at all, the worms lag behind and usually die.

Eggs laid on the same day hatch almost at the same time. If any eggs of the same lot fail to hatch within two days of first hatching of the batch, they should be rejected as not quite healthy.

Eggs lose in weight as they approach maturity :

100 eggs laid 17 September (night).

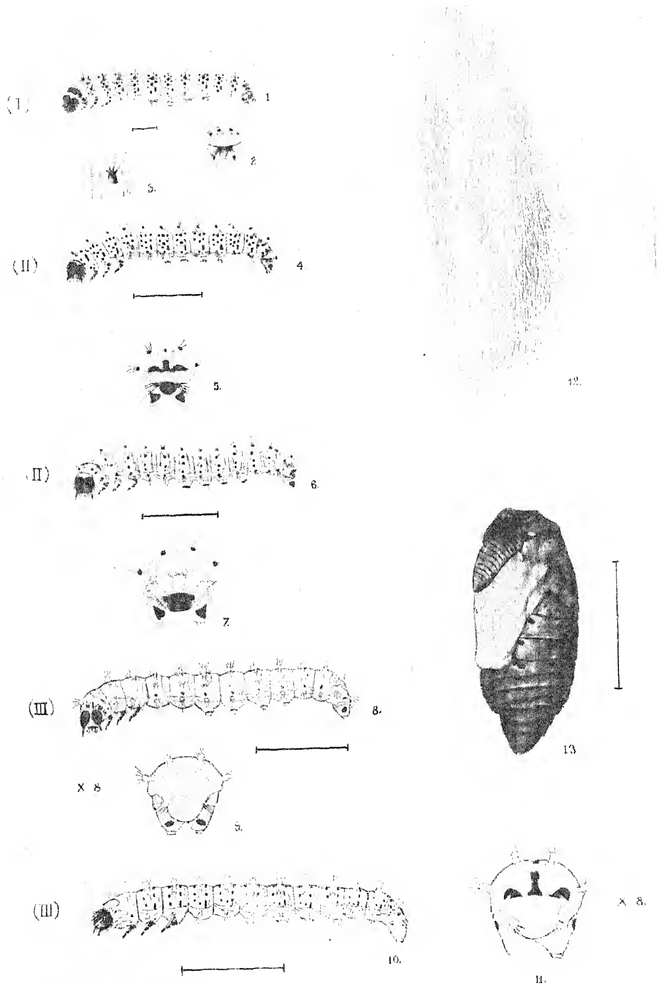
Weighed on	18-9	2·65 grains.	
,, ,,	21-9	2·56 ,,	
,, ,,	23-9	2·43 ,,	
,, ,,	25-9	2·35 ,,	(Hatched).

98 newly hatched worms weighed 1·80 grains.

5. Description of the Stages of the Worm.

First Stage.—Length about 5 m.m. The body is cylindrical with distinct segments. The head is black, shiny. There is a black prothoracic shield. The general colour of body, when just hatched,

PLATE V.



YOUNG ERI WORMS.

Engraved and Printed by The Calcutta Phototype Co.

EXPLANATION OF PLATE V.

Fig.	1.	Worm in first stage.						
,,	2.	,,	,,	,,	anal view.			
,,	3.	,,	,,	,,	tubercle more highly magnified.			
,,	4.	,,	,, second stage,		black-spotted.			
,,	5.	,,	,,	,,	,,	anal view.		
,,	6.	,,	,,	,,	,,	unspotted form.		
,,	7.	,,	,,	,,	,,	,,	,,	anal view.
,,	8.	,,	,, third	stage,		,,	,,	
,,	9.	,,	,,	,,	,,	,,	,,	anal view.
,,	10.	,,	,,	,,	,,	spotted form.		
,,	11.	,,	,,	,,	,,	,,	,,	anal view.
,,	12.	Cocoon.						
,,	13.	Pupa removed from cocoon.						

is pale yellow ; in the course of a day a slightly greenish tinge is developed ; but the colour becomes deeper yellow later on.

From mesothorax to 7th abdominal segment, each segment has got five pairs of black spots, all the spots making up 5 rows (of black spots on the back), *viz.*, 1 median, 2 submedian and 2 lateral or spiracular ; with the spiracle where present a segment shows 3 black spots along this row, the posterior of them being oval and elongated. On the prothorax, the region of the median and submedian spots is occupied by the shield ; also the spiracular spots are not distinct. In the posterior segments the spots are not so distinct.

From prothorax to the 7th abdominal segment, each segment has got six small fleshy tubercular spines, mounted with a varying number of hairs (hairs varying from 2 in some to 9 in others). These fleshy spines are arranged in longitudinal rows which alternate with those of the black spots. On each of the three thoracic segments there is a fourth smaller spine on each side just above the leg. On the prothorax the four upper spines are on the shield. On the 8th abdominal segment there are only five such fleshy spines, one in a line with the middorsal row of black spots and two on each side. On the 9th abdominal segment, there are only four such spines alternating in position with those on the preceding segment. When hatched from the egg, these spines are yellow with the hairs whitish ; but in the course of about 12 hours, the spines as well as the hairs on them become black, when the larva looks much black-spotted.

The anal shield is black and prominent and has got two very small similar spines on it. The prolegs are all developed ; the four pairs of abdominal ones are yellow with the tips blackish ; the bases of the anal prolegs are black on the outside.

In later stages these fleshy spines become very big and prominent, while the hairs on them become less in number and very short.

From the second stage onwards the black spots are retained in some larvæ ; while in others they altogether disappear in the second stage ; in a few, a few of the black spots may be present very faintly till the third stage and then disappear. The two kinds of larvæ are very distinct in the advanced stages, *viz.*, black-spotted

ones and unspotted ones. The presence or absence of black spots is not indicative of sex; both kinds may turn into either male or female moths. The offspring of either has been seen to be spotted and unspotted mixed. If only unspotted ones are bred, the majority tend to be unspotted. On the other hand, if spotted ones are bred, the majority tend to be spotted. From the very beginning the majority of the worms in all the broods were unspotted, the spotted ones being not more than ten per cent.; in some cases they were much less. Some spotted worms were made to spin separately; from these both females and males emerged; of the worms from the eggs of these moths more than 50 per cent. (but not all) were black-spotted. In other baskets of worms from eggs of moths of spotted and unspotted worms kept mixed together as ordinarily done, the percentage of black-spotted worms was 2 to 10. In this way it is possible to eliminate either spotted or unspotted worms wholly. The presence or absence of the black spots in the worms in the later stages seems to be an accident as in the early stage all the worms possess these spots.

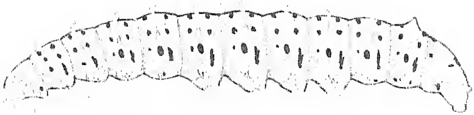
Second stage.—Length about 12—15 m.m. Head black, shiny. The prothoracic shield is now reduced to two black markings at the posterior part of the prothorax, one being on each side of the median line and both elongated transversely. The four upper fleshy spines on the prothorax are placed on its anterior part and thus apart from the reduced shield. The general colour is yellow, but not so deep as in the first stage. All the fleshy spines on the body have become yellow, but their tips remain black. The black anal shield has got a pair of distinct spines mounted with hairs.

In some the black spots have disappeared; in a few a faint row of median faint spots is present. In the others which have retained the black spots, the spots on the posterior segments have become very distinct, the median spine on the eighth abdominal segment has got one spot anteriorly and 2 spots posteriorly to itself; also on the posterior part of the 9th abdominal segment there have been developed three big black patches alternating in position with the spines on the segment and joined to one another. (These patches are not present on the unspotted worms.)

PLATE VI.

1.

2.



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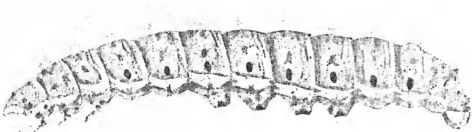


6.

ERI WORMS IN LATER STAGES.

EXPLANATION OF PLATE VI.

Fig.	1.	Worm	in	fourth	stage,	spotted form.		
,,	2.	,,	,,	,,	,,	,,	,,	anal view.
,,	3.	,,	,,	fifth (last)	,,	,,	,,	
,,	4.	,,	,,	,,	,,	,,	,,	anal view.
,,	5.	,,	,,	,,	,,	unspotted white form.		
,,	6.	,,	,,	,,	,,	,,	green form.	

Just after the first moult, the head is pale yellowish-white, the body and legs are pale yellow ; in the case of unspotted worms only the spiracles are black ; over and above these, black spots are present in the case of the spotted ones with the black patches on the posterior part of the 9th abdominal segment.

Third stage.—Just after the second moult, the head is yellowish white as also the legs and spines ; the general colour is pale yellow. As after every moult, the black spots are present in the case of the spotted worms. In the course of about 24 hours the colour changes to white and the head becomes black.

In this stage the worms are about 18—21 m.m. long. The head is black. The cervical shield is now further reduced to two faint black markings on the posterior part of the prothorax. The thoracic legs are black as also the small spines just above the thoracic legs : in some the tips of the lateral spines are black. The spines are thick and knoblike at the top. The anal shield is no longer black but slightly greenish white. The black patches on the posterior part of the 9th abdominal segment (in the case of the spotted worms) are now detached into three distinct patches, the middle one being somewhat of the shape of a dumb-bell.

Fourth stage.—The length is about 40 m.m. The head is very slightly greenish yellow or yellow ; there is a somewhat big black patch near the posterior margin of each lobe ; a blackish patch is present on each cheek containing the ocelli. There is no trace of the prothoracic shield. Thoracic legs are yellow. The colour is white and covered with a white powdery substance or bloom.

Fifth stage.—In this stage the larvæ eat enormously and so grow very quickly. The well-fed full-grown larvæ are about 95 to 100 m.m. long. The abdominal part is about 15 m.m. thick. The general shape is cylindrical and tapers prominently forward ; the thoracic segments with the head may be kept contracted, so the larva may not always look so tapering. The head is yellow with the blackish patch on each cheek containing the ocelli. Of the three black patches on the posterior part of the 9th abdominal segment of the black-spotted worms, the two on the two sides have almost disappeared

or linger as faint black markings, the dumb-bell-shaped middle one is also reduced and makes a figure of 8 (in some the lower circle is about half cut like 8).

The general colour is white. Some become beautifully green. Those which remain white turn yellow before spinning. In those which have got an excess of the white powdery substance, the yellow colour is not so prominent. The green worms develop beautiful pink spots on the tips of the fleshy spines on the body.

The worms in the different stages can be easily distinguished by the following characteristics :—

First stage.	Black head. Undivided big prothoracic shield. Yellow body.
Second stage.	Black head. Divided prothoracic shield. Yellow body.
Third stage.	Black head. White body.
Fourth stage.	Yellow head with the black patches on the posterior margin of each side. (Also in the case of spotted worms the detached dumb-bell-shaped black spot on the posterior part of the 9th abdominal segment.)
Fifth stage.	Yellow head without the black patches on the posterior margin of the lobes. Later on in the stage the big body tapering anteriorly. (In the case of the spotted worms 8- or Ω- shaped black markings on the posterior part of the 9th abdominal segment.)

6. Life of the Worm.

Resinous Secretion.—The worms secrete a white resinous substance which covers the entire surface of the body in the form of a white powder such as is found covering the stems and leaves of many

varieties of castor. Worms which are fed with great care show an excess of this substance. Again, worms which are allowed to feed at will on living plants secrete a still larger quantity. Therefore, the secretion of this substance is indicative of health and vigour in the worm.

Process of Moulting.—The larva ceases to eat for some time and rests almost motionless for 1 to 3 days according to temperature. At this time it does not like any disturbance. During the period of rest the head gets somewhat detached, showing a sort of a neck behind. The whole period of the rest seems to be spent in extricating the head from the head-moult and then the skin soon glides off behind. The head-moult remains attached to the skin at the throat and is cast off with the skin. The cast skins are never eaten.

Life-cycles.—The following table gives the dates and durations of broods at different seasons of the year; they vary from 37 to 85 days normally, but with the spell of cold which comes once usually in each cold weather, the duration of one brood may go up to 100 days and over.

	Eggs laid.	Eggs hatched.	Worms spun.	Moths out.	Periods.	Total.
1	11-I-1908	4-II	10-III	31-III	24-35-21	80
2	20-I-1908	13-II	17-III	4-IV	24-33-19	76
3	2-III-1908	15-III	7-IV	24-IV	13-23-17	53
4	31-III-1907	8-IV	26-IV	14-V	8-18-18	44
5	9-V-1907	17-V	5-VI	22-VI	8-19-17	44
6	24-VI-1907	1-VII	17-VII	2-VIII	7-16-16	39
7	29-VI-1907	6-VII	22-VII	6-VIII	7-16-15	38
8	1-VII-1907	9-VII	27-VII	14-VIII	8-18-17	43
9	4-VIII-1907	10-VIII	26-VIII	10-IX	6-16-15	37
10	19-VIII-1907	26-VIII	10-IX	26-IX	7-15-16	38
11	22-IX-1907	29-IX	15-X	30-X	7-16-15	38
12	26-IX-1907	3-X	26-X	16-XI	7-23-21	51
13	9-XI-1907	20-XI	8-I	28-II	11-49-51	111
14	24-X-1907	2-XI	27-XI	24-I	8-25-54	87
15	3-VIII-1908	10-VIII	26-VIII	10-IX	7-16-15	38
16	7-VIII-1908	14-VIII	30-VIII	14-IX	7-16-15	38
17	8-VIII-1908	15-VIII	1-IX	16-IX	7-17-15	39
18	13-VIII-1908	21-VIII	4-IX	21-IX	8-14-17	39
19	13-IX-1908	21-IX	6-X	25-X	8-15-19	42
20	27-X-1908	6-XI	12-XII 23-XII	16-I 4-II	10-36-35 10-47-43	81 100
21	14-XI-1908	26-XI	17-I	24-II	12-52-38	102

	Eggs laid.	Eggs hatched.	Worms spun.	Moths out.	Periods.	Total.
22	20-I-1909	9-II	19-III	8-IV	20-38-20	78
23	1-III-1909	12-III	12-IV	28-IV	11-31-16	58
24	3-V-1909	10-V	28-V	12-VI	7-18-15	40
25	14-VI-1909	22-VI	10-VII	25-VII	8-18-15	38
26	27-VII-1909	2-VIII	17-VIII	2-IX	7-17-15	39
27	19-VII-1909	25-VII	10-VIII	25-VIII	6-16-15	37
28	23-VII-1909	29-VII	13-VIII	28-VIII	6-15-16	37
29	5-IX-1910	12-IX	30-IX	19-X	7-18-20	45
30	21-X-1910	1-XI	27-XI	19-I	10-26-53	89

When the eggs turn grey, it is an indication that they are going to hatch within a day or two. At this time they should be fairly spread, so that they are not heaped and one layer of tender leaves of castor spread on them. Each leaf may be torn into 2 or 3 pieces, so that the leaves may almost touch the eggs on which they are placed. Soon after hatching, the worms will crawl up to the underside of the leaves. The leaves are now transferred to a separate tray and turned up so that the worms are above. Fresh leaves are placed on the eggs for other worms to crawl up which can be similarly transferred. The transferred worms are now fed with pieces of fresh tender leaves spread on them. It is unwise to chop the leaves into small pieces, as in that case they dry soon, specially in dry seasons. It is better to take entire leaves in the hand and supply by tearing them into small pieces. When the season is not dry, it is enough if leaves are supplied twice daily to the young worms. In dry seasons care is to be taken to see how soon the leaves are drying and fresh food is to be supplied accordingly, so that the worms may not starve, as they never eat dry leaves. Much greater care has to be bestowed on the worms when they are young than when they are grown. Cleaning of the baskets is done by transferring the worms to a separate tray. When the worms are grown, this can be done easily by placing fresh leaves on the worms which will soon crawl up to the leaves and can be transferred with the leaves. In this way all the worms in a tray can be transferred without handling them roughly. When young, they do not come up to the fresh leaves so soon and cling to the old leaves; these old

leaves are therefore to be transferred carefully with the worm which can then be fed.

If the season is not unfavourable and the leaves do not get dry, generally the number of times the worms are to be fed are the following :—First stages—twice.

Second and third stage—three times (once at night).

Fourth stage—four times (once at night).

Fifth stage—five times (or if possible six times) (once at night or if possible twice at night).

These, however, are not hard and fast rules. The number of times the food has to be supplied will depend much on the quantity supplied each time. When the worms are in the process of moulting, they do not require any food at all, and it is better to leave them quite undisturbed. Food need not be supplied to the worms just after they have emerged from a moult. It is better to leave them without any food for about six hours till they are well out of the sickness. They will themselves signify their hunger by crawling about in search of food.

Worms of different ages should never be kept together; some go into moult while others feed and are active; those in moult therefore are not left at ease. Besides, as the worms grow, their activity increases; the bigger ones therefore cause a great deal of inconvenience to the younger ones. This is very harmful especially in the later stages; when young, the worms are usually in the habit of feeding from the underside of the leaves supplied; the big worms are more active and show a tendency to get upon the leaves and choke the young ones which may be kept with them; in such cases it has been seen that the mortality among the younger ones is very high. Of the worms which hatch on the same day, some grow more quickly than the others and it is better to separate them if possible.

In rearing the worms the less crowded and the more clean they are kept, the better. Young worms require tender leaves; older leaves are to be supplied as they grow old. The leaves should not be covered with dust and as far as possible should not be wet.

In March, April, May, when west winds blow and cover all leaves in the field with dust, we have to wash the leaves before supplying them to the worms. Usually high temperatures prevail about this time and it does not matter if the leaves supplied are not completely and perfectly dry. In the wet season the leaves should be as far as possible not wet. But if the choice lies between only partially wet leaves and leaves which have dried up and lost much of the natural moisture, the former should be preferred.

When full-grown and about to spin cocoons, the worms which are white turn yellow; the green ones remain green. It is easy to determine whether any worm is ready for spinning; hold the worm with your finger near your ear and pass the fingers lightly over the fleshy spines; if the worm is ready for spinning, a hollow sound will be clearly perceptible; if not, the sound will be dull and solid. In the worms which turn yellow, the yellow colour is a sufficient indication that they are ready for spinning. With the green ones the sound has to be tested. Expert hands can detect a softer feel and a lighter weight in those ready for spinning, but this distinction is very fine. It would be very difficult if the sound test had to be applied to every individual worm, especially when a large number has to be picked for spinning. There is a definite time every day when the worms seek to spin; this is between 9 and 12 in the morning: the largest number come up at about 10-30 or 11 A.M. Some worms spin in the feeding baskets at night; but their number is small and they are mostly those which ripen late, and are left in the baskets.

When the worms get ready for spinning, they cease feeding and pass a large quantity of excrement a part of which is semi-solid and the rest yellow-coloured liquid; at this time they sit with the thoracic segments contracted and raised upward with the head; and they present a sickly appearance. After a while, they become active and roam about in search of a place for spinning and come up to the edge of the tray. The best time to pick up the worms for spinning is when they have thus come up to the edge of the tray. If they are picked before this, they may soil the spin-

PLATE VII.

Putting Worms to spin.

ning materials by their liquid excreta. Besides, when spinning has commenced in a brood, almost all the worms which between 9 A.M. to 12 noon thus leave their food and come up to the edges of the baskets and walk about, can be taken to be such as want to spin; among them the number of unripe worms will be very small—less than 1 per cent. The ripe worms require a hidden corner to form cocoons or any material in which they can hide themselves and find a space for the cocoon, *e.g.*, crumpled paper, pine shavings, dry straw, dry leaves, etc. It is best to supply a material which can afford tolerably big interspaces. A layer of this material is placed at the bottom of the basket and a number of worms dropped in; then another layer of the material with more worms is put in; in this way the whole basket is filled up and covered. About 500 worms can be very conveniently made to spin in a basket about $1\frac{1}{2}$ ft. in diameter and about $1\frac{1}{4}$ to $1\frac{1}{2}$ ft. in depth. The worms have got a tendency to come upwards, and care should always be taken to see that no empty space is left below the lid; the basket should be fully filled with the material; otherwise many worms will collect in this empty space and cover the whole under-surface of the lid with silk without using it in the cocoons; a sort of a netted cloth is then produced and also many double cocoons are formed. After filling the basket, a weight has to be put on the lid so that no worms may get out, or the basket may be turned upside down.

Something has already been said about how the worms can be made to spin. If baskets are used, they should be of the kind of those used for packing fresh fruits (litchi baskets), so that air may pass through all the sides; also the best spinning medium is that which affords interspaces all through. In the process of spinning, the worms evolve heat, which must be let out, or it chokes and kills the worms and causes them to rot within a few days. Also the worms spin well, pupate successfully and the pupæ keep well, if ventilation can be kept up through the interspaces of the spinning medium and the sides of the basket, and if free breathing is not interfered with. Some worms were put in a packing case for

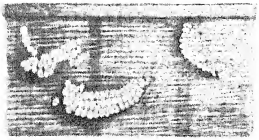
spinning and its lid was removed, the mouth being kept covered with a cloth: about three-fourths of the worms died without spinning; of the rest, those only were good which were at the top. If the spinning basket is a very big one, although its sides may allow passage of air, care should be taken that the worms in the interior are not overpressed and that proper inter-spaces are left in the interior, otherwise the worms there may not spin properly and may die for want of proper breathing. The worms finish spinning in about three days and rest inside the cocoons before turning into pupæ for about one to three days according to temperature. The cocoons can be picked out from the spinning medium after five days in summer and eight days in winter. The baskets can then be used for a fresh lot of worms.

Usually two kinds of cocoons are prepared by the worms, *viz.*, white and red-brown. The colour of the worms, or the presence or absence of spots in them, has nothing to do with the colour of the cocoon. The green as well as the white worms or the spotted as well as the unspotted worms may form either white or red-brown cocoons. It has been observed that worms reared from eggs of moths from white cocoons may form both white and red cocoons, also both red and white cocoons are formed by worms from eggs of moths from red cocoons If, however, only the moths from white cocoons are bred, the red cocoons will gradually disappear and *vice versâ*. In this way, either the white or the red-brown cocoons can be wholly eliminated. Complete elimination can be effected so soon as in the third or fourth generation. It has been suggested that worms spinning in darkness form white cocoons. But it has been definitely proved by making the worms spin in glass dishes in the glare of the sun and also in darkness, that the presence or absence of light is not at all a determining factor in the colour of cocoons. The colour of the red-brown cocoons is not permanent; it disappears when the cocoons are boiled with ashes or soda, but the yarn from them is not so white as that from the white cocoons. Rarely pink cocoons are formed and also cocoons with a slightly greenish tinge; but when the moths from these

EXPLANATION OF PLATE VIII.

Fig. 1. Eggs as laid in clusters.
" 2. A single egg, highly magnified.
" 3. A pierced cocoon.
" 4. " " " the floss removed.
" 5. Cocoon, white variety.
" 6. " yellow "
" 7. " pink "
" 8. Cocoon cut, open longitudinally.

PLATE VIII.



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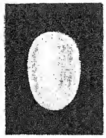

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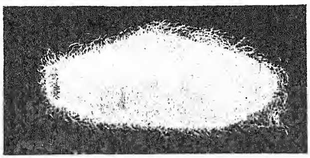

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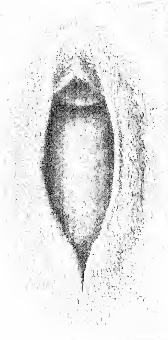

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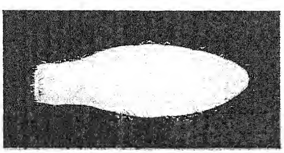
6.

7.



4.

EGGS AND COCOONS OF ERI MOTHS.

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were bred, the cocoons formed were almost all white. In one case at least it was seen that the pink cocoon was formed by an unhealthy worm. The colour of the food also has nothing to do with the colour of the cocoons ; some worms were fed specially on only red castor leaves but they formed white cocoons.

The rearing at Pusa commenced with seven pairs of moths from cocoons obtained in Kamrup, Assam. The cocoons reared from these in all the generations were all white. Later on, on two occasions we imported eggs and seed cocoons from Gauhati and other places. On both occasions there was a sprinkling of red-brown cocoons. As we did not breed from these red cocoons, they disappeared soon and we obtained only white cocoons. Recently some experiments have been undertaken in crossing Eri silk moths, *Attacus ricini*, Boisd., with *Attacus cynthia*, Drury, which is considered by some as the wild original form of *Attacus ricini*. (The results of this experiment will be published in a future publication.)

The crosses have produced both white and red-brown cocoons. In Assam the rearers generally get both brown and white cocoons. This may probably be due to the fact that they often expose the female moths in such a way that they have a chance of being fertilised by *A. cynthia* which is said to occur wild in some parts of Assam.

There are other methods of allowing the worms to form cocoons which are sometimes as efficacious as the above. One is the use of the *Chandraki* or Spinning Frame of Bengal (Fig. 9) used in mulberry silk. We have tried it, and in damp weather it is successful but takes up much space. In dry hot weather it is unsuitable. Another method is to suspend cloth over horizontal bamboos, so that long folds hang down and to let the worms crawl into the folds to spin. Very clean cocoons can be got in this way and they are readily detached from the cloth ; also very little silk

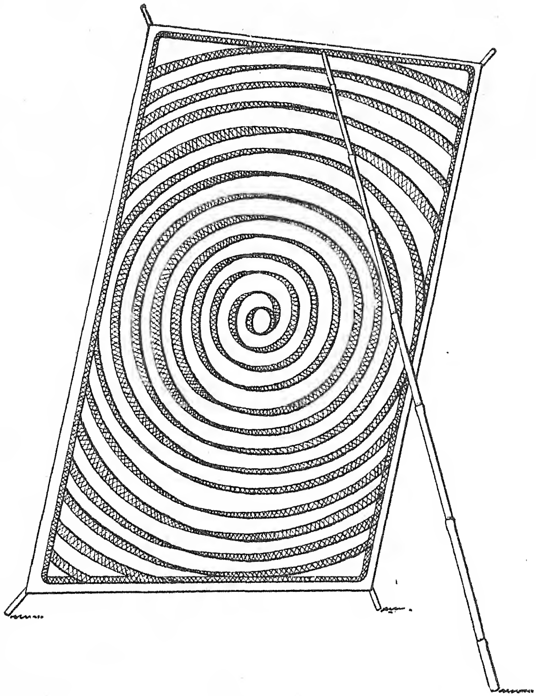


FIG. 9.

is wasted in the cradle or cocoon-foundation. The method requires less space, saves packing material and baskets and is useful when rearing is being done on any large scale.

The following tables give the weights in grains of food, larva, etc., for three individual worms: the first figure is the weight of

food given; the second is the weight of the same amount of food kept for the same time, as a guide to the loss from evaporation; the third is the weight of the larva; the fourth is the food left; the fifth is the excrement. Were there no evaporation, etc., then the increase of the weight of the larva should equal the difference between the weight of food after evaporation (column 3), and the combined weight of food left (column 5) and the excrement (column 6). In all cases the eggs were laid on 30-III, hatched 7-IV, the weight of 100 eggs being 3 grains and of 100 larvæ about 2 grains.

(A.)

Date.	Food given in grains.	Weight of equal quantity of food kept for same time in grains.	Weight of larva in grains.	Food left in grains.	Excrement in grains.
10-IV	4	3·1	·1	2·3	·06
11-IV	moult.				
12-IV	5	4·3	·36	3·9	·12
13-IV	5	3·5	·7	2·9	·17
14-IV } moult }	5	4·5	·8	4·1	·18
15-IV	5	4·4	1·6	3	·3
16-IV	10	8·9	3·5	5·3	1·3
17-IV } moult }	15	14·1	3·9	12·2	·8
18-IV	15	13·7	6·5	8·6	1·8
19-IV	20	18·6	14·75	5·7	3·8
20-IV	30	27·8	24·2	8·2	8·4
21-IV } moult }	30	26	23·8	21·4	1·5
22-IV	50	47	41	17·7	10
23-IV	50	47	62·6	6·5	18·8
24-IV	100	94·5	94·2	10·6	48·1
25-IV	120	114	120·1	29·5	54·5
26-IV	90	83	126	23·8	66·1

Then it spun up.

Weight of pupa-cocoon 13 days after spinning 47·4 grains.

Male emerged 15th May.

Weight of pierced cocoon	8·2	grains.
,, dried larval exuvium	·2	,,
,, pupal ,,	·9	,,
,, cocoon	7·1	,,
Floss	3·7	,,
Shell	3·4	,,

(B.)

Date.	Food given in grains.	Weight of equal quantity of food kept for same time in grains.	Weight of larva in grains.	Food left in grains.	Excrement in grains.
10-IV	4	3·1	·1	·05	2·6
11-IV	moult.				
12-IV	5	4·3	·35	·12	4·2
13-IV	5	3·5	·7	·25	3·5
14-IV moult	5	4·5	·7	·09	4·3
15-IV	5	4·4	1·45	·3	3·3
16-IV	10	8·9	3·2	1·1	5·9
17-IV moult	15	14·1	3·2	6	12·8
18-IV	15	13·7	5·35	1·4	9·2
19-IV	20	18·6	11·3	3	8·2
20-IV	30	27·8	21·3	6·4	10·3
21-IV moult	30	26	20·8	1·8	21·4
22-IV	50	47	32·9	7·3	25·8
23-IV	50	47	56·2	16·6	5·5
24-IV	100	94·5	85·5	38·9	24·5
25-IV	120	114	100·4	61·5	42
26-IV	90	83	91·6	58·9	33·6

Spun on the 27th.

Male emerged 14th May.

Weight of cocoon and pupa 13 days after spinning	36·8
„ „ „ pierced	6·8
„ „ dried larval exuvium	·2
„ „ „ pupal „	·8
„ „ cocoon only	5·8
„ „ Floss	2·4
„ „ Shell	3·4

(C.)

Date.	Food given in grains.	Weight of equal quantity of food kept for same time in grains.	Weight of larva in grains.	Food left in grains.	Excrement in grains.
10-IV	4	3·1	·1	2·4	·06
11-IV	moult.				
12-IV	5	4·3	·32	3·6	·10
13-IV	5	3·5	·65	3·2	·2
14-IV	5	4·5	·7	4·4	·15
15-IV	5	4·4	1·35	3·4	·3
16-IV	10	8·9	3·1	6·1	·8
17-IV	15	14·1	3·3	11·8	·7
18-IV	15	13·7	6·1	8·8	1·2
19-IV	20	18·6	12·5	7	3·9
20-IV	30	27·8	20	13·2	5·8
21-IV moult	30	26	19·5	24	1·3
22-IV	50	47	32·3	24·3	8·6
23-IV	50	47	52·2	5·8	19·8
24-IV	100	94·5	84·6	14·5	39·3
25-IV	120	114	98·3	37·6	59·6
26-IV	90	83	101	26	59·8

Spun on 27th.

Male emerged 14th May.

Weight of cocoon and chrysalis 13 days after spinning	38·8
,, ,, ,, pierced	6
,, ,, Larval exuvium	·2
,, ,, Pupal ,,	·9
,, ,, cocoon only	4·9
,, ,, Floss	2
,, ,, Shell	2·9

These figures illustrate clearly the daily growth of the larva, till it commences to spin; it attains a weight of over 100 grains, then spins and there is a loss of sixty grains at once, probably mainly moisture from the skin but also from the silk and from exuvium at moulting. Actually only five grains of dried silk compose the cocoon. The total food fed was 554 grains, of which 196·2 was rejected and 200 grains of excrement were obtained. Actually in this case (No. 3), of about 550 grains of leaf fed, about 200 is waste, 200 is excrement; this has an importance in considering the manurial requirements of the castor crop, since if 110 maunds of leaf were picked per acre, 40 maunds of leaf and 40 maunds of excrement would be available per acre to go back. For further details, see the tables below for larger quantities of worms.

Records were kept very carefully for four worms and are as follows :—

Food supplied in grains.		Food consumed in grains.	Excrement in grains.
(1) ..	645	348·7	215·93
(2) ..	645	379·8	241·33
(3) ..	645	297·8	198·31
(4) ..	645	319·2	201·61
TOTAL ..	2,580	1,345·5	857·18
Average for 1 worm	645.	336	214
For 10,000 worms,	115 mds. 7 srs.	60 mds.	38 mds. 8 srs.

In the above the weight of excrements shows the weight when the excrements were not dry.

Below are given actual figures for several broods; the food supplied was weighed fresh: the wasted leaves and excrements were weighed when they were dry or nearly dry:—

(1).	Leaves supplied	11 mds.
	„ wasted	1 md. 39 srs.
	Excrement	2 mds. 27 srs.
	Pierced cocoons secured ..	5½ srs.
	Approximate number of cocoons ..	13,278.
(2).	Leaves supplied	19 mds.
	„ wasted	3 „ 14 srs.
	Excrement	3 „ 36½ „
	Cocoons secured	9½ srs.
	Approximate number of cocoons and of worms which spun these cocoons	25,000.
(3).	Leaves supplied	49½ mds.
	„ wasted	5 „ 30 srs.
	Excrement	12 „
	Cocoons secured	19 seers.
	Approximate number of cocoons ..	76,000.
	Eggs kept by weight about ..	120,000.
	(In this brood the mortality was very high at the time of spinning).	
(4).	Leaves supplied	77½ seers.
	„ wasted	16¼ „
	Excrement	12¾ „
	Cocoons got about	1 seer.
	Number of the cocoons	2,418.
	Eggs kept by weight about ..	5,550.
(5).	Leaves supplied	25 mds. 23½ srs.
	„ wasted	5 „ 8½ „
	Cocoons	7½ seers.
	A large amount of leaves had to be supplied as they were drying quickly on account of the West winds.	
(6).	Leaves supplied	9 mds. 31 srs.
	„ wasted	2 „ 16 „
	Cocoons	5¾ seers.
	Appproximate number of the cocoons	14,503.

Twenty-five cocoons (pierced) taken at random weigh as follows: —

1	weighs	8·0	grains.
1	„	7·7	„
1	„	7·6	„
3	weigh	7·2	„
1	weighs	6·8	„
1	„	6·7	„
2	weigh	6·6	„
2	„	6·5	„

4	weigh	6·4	grains.
2	„	6·3	„
2	„	6·2	„
3	„	6·1	„
1	weighs	5·8	„
1	„	5·2	„

Average 6·5 or 1,077 to the lb.

The last was composed of :

Pupa case	1·3
Larval skin	·2
Cocoon	3·7
(Floss	·85)
(Shell	2·85)

Twenty-five unpierced cocoons, dead and dried, weighed as follows :—

19·1, 18·7, 18·0, 17·9, 17·7, 17·5, 16·9, 16·9, 15·4, 15·3, 14·3, 14·0, 13·7, 13·7, 13·3, 13·3, 13·0, 12·8, 12·3, 12·3, 11·8, 11·6, 11·2, 10·8, 10·1.

Average 14·4, or about 487 to the lb.

The heaviest was composed as follows :—

Pupa	12·4	
Larval skin	·3	19·1
Cocoon	6·4	
(Floss	2·15)	
(Shell	4·25)	

The lightest :

Pupa	5·6	
Larval skin	·3	10·1
Cocoon	4·2	
(Floss	1·2)	
(Shell	3·0)	

Figures of the weights of live unpierced cocoons are given above ; others are :

Pupa	39·9	
Larval skin	·25	45·4
Cocoon	5·25	
(Floss	1·5)	
(Shell	3·7)	

Pupa	30·8	
Larval skin	·5	36·3
Cocoon	5·0	

Below are given some more figures showing the percentage of larval and pupal exuvia in the pierced cocoons.

Weight of pierced cocoon.	Weight of silk obtained from same before boiling (*i.e.*, excluding the empty pupa case and the last larval moult).
6·2 grs.	5·1 grs.
6 „	5 „
8·2 „	7·1 „
6·8 „	5·8 „
6 „	4·9 „
5·2 „	3·7 „
7·5 „	6·4 „
5·4 „	4·2 „
51·3 „	42·2 „

A lot of 100 cocoons weighing 641 grains contained 540 grs. of silk.

Therefore on an average the weight of the empty pupa cases and the last larval moults (which remain inside the pierced cocoons) is about 16 per cent. of the weight of the pierced cocoons. The same percentage is observed when larger numbers of cocoons are taken.

The following table gives figures for six worms of which the sex was noted :

No.	Maximum weight of larva.	Sex of Moth.	Weight of silk only.
1	84	Female	5·0
2	72	..	5·3
3	88	..	5·1
4	77	..	5·5
5	95	Male	5·3
6	72	..	4·3

History of the Pusa Broods.

The following account of broods gives the periods at different seasons, as well as other important facts :—

First Brood.—25th March 1907, seven couples of moths hatched from cocoons obtained in Kamrup, Assam. They laid about 2,000 eggs (by weight) between the 27th and 31st March. These eggs hatched between the 4th and 10th of April, the worms spun cocoons between the 20th and 28th April and moths emerged again from the 7th to 15th April. One moth laid 415 eggs, another 188, another 354 ; the average for well-fed healthy moths is about

300. Four individual worms of this brood were recorded separately :

Eggs laid	31·III.	31·III.	31·III.	31·III.
„ hatched	8·IV.	8·IV.	8·IV.	8·IV.
Cocoon formed	26·IV.	26·IV.	26·IV.	26·IV.
Moth emerged	15·V.	14·V.	14·V.	14 V.
	45 days.	44 days.	44 days.	44 days.

Second Brood.

Eggs laid	9-V to 15-V.
„ hatched	17-V to 22-V.
Cocoons formed	5-VI to 17-VI.
Moths emerged	22-VI to 27-VI.
	44 days.

In this brood the cocoons were small, 4,000 to the seer, owing to the difficulty of getting food which had to be carted five miles and which was not fed fresh to the worms, owing to the time taken in carting and to its not being procurable as wanted. About 40,000 cocoons were obtained.

Third Brood.

Eggs laid	24-VI to 1-VII.
„ hatched	1-VII to 9-VII.
Cocoons formed	17-VII to 27-VII.
Moths emerged	2-VIII to 14-VIII.
	38 days.

In this brood, 13,278 cocoons were obtained, but about 700 moths failed to emerge from the cocoons (a sign of weakness) and rats ate or cut about 950. Nearly 500 worms died before spinning, mostly when quite young. The cocoons were larger, the worms being fed from a plot of castor nearer at hand and about 2,500 went to the seer. About $10\frac{3}{4}$ maunds of leaf were fed to this brood, thus making about 83 maunds of leaf to 100,000 worms which would produce a maund of pierced cocoons. For this brood, details are given of the daily food supplied, as a guide to the amount required, which of course increases as the worms increase in size.

9-VII	Leaves	3 seers.	14 chittacks.
10-VII	Leaves	5 seers.	14 „
	Wastage ..		11 „

	Excrement ..		5 chittacks.
11-VII	Leaves ..	12 seers.	
	Wastage ..		12 ,,
	Excrement ..		10 ,,
12-VII	Leaves ..	11 ,,	6 ,,
	Wastage ..	1 ,,	2 ,,
	Excrement ..	1 ,,	2 ,,
13-VII	Leaves ..	11 ,,	8 ,,
	Wastage ..	1 ,,	
	Excrement ..	1 ,,	6 ,,
14-VII	Leaves ..	17 ,,	10 ,,
	Wastage ..	1 ,,	4 ,,
	Excrement ..	1 ,,	2 ,,
15-VII	Leaves ..	22 ,,	
	Wastage ..		6 ,,
	Excrement ..	1 ,,	8 ,,
16-VII	Leaves ..	41 ,,	13 ,,
	Wastage ..	2 ,,	6 ,,
	Excrement ..	6 ,,	
17-VII	Leaves ..	41 ,,	10 ,,
	Wastage ..	3 ,,	10 ,,
	Excrement ..	12 ,,	
Spinning commenced (500 Spun).			
18-VII	Leaves ..	39 ,,	10 ,,
	Wastage ..	3 ,,	8 ,,
	Excrement ..	7 ,,	8 ,,
Spinning continued (776 Spun).			
19-VII	Leaves ..	25 ,,	10 ,,
	Excrement and Wastage ..	20 ,,	8 ,,
Spinning continued (1,090 Spun).			
20-VII	Leaves ..	44 ,,	4 ,,
	Wastage ..	7 ,,	10 ,,
	Excrement ..	9 ,,	6 ,,
	Dead 12.		
21-VII	Leaves ..	31 ,,	14 ,,
	Wastage ..	5 ,,	10 ,,
	Excrement ..	13 ,,	2 ,,
Spinning continued (1,500 spun).			
	Dead 80.		
22-VII	Leaves ..	36	5 ,,
	Wastage ..	10 ,,	4 ,,
	Excrement ..	16 ,,	12 ,,
Spinning continued (1,444 Spun).			
	Dead 107.		
23-VII	Leaves ..	37 ,,	6 ,,
	Wastage ..	8 ,,	7 ,,
	Excrement ..	8 ,,	14 ,,
Spinning continued (800 Spun).			
	Dead 73 (partly eaten by rats).		
24-VII	Leaves ..	40 seers.	13 ,,
	Wastage ..	4 ,,	12 ,,
	Excrement ..	6 ,,	6 ,,

Spinning continued (1,200 Spun).
Dead 24.
4 eaten by rats.
5 died at moult.
15 diseased.

25-VII Leaves	..	15 seers.	4 chittacks.
Wastage	..	9 „	2 „
Excrement	..	6 „	4 „

Spinning continued (1,200 Spun).
Dead : 5 failed to spin.
6 ; rats ate them.
13 failed to moult.
13 diseased.

26-VII Leaves	..	9 seers.	10 chittacks
Wastage	..	9 „	12 „
Excrement	..	3 „	

Spinning continued (1,435 Spun).
Dead : 12 ; rats ate them.
3 failed to moult
13 could not spin
10 diseased.

27-VII Leaves	..	4 seers.	3 chittacks.
Wastage	..	1 seer	
Excrement	..		8 „

Spinning continued (340 Spun).
Dead : 8 ; rats ate them.
12 could not spin.

The above figures show several interesting points ; they are not complete for the whole brood, but they show how the feeding has to be done and what weight of matter is obtained as excrement and wastage which should all go back to the land as manure. The disease was also a distinct factor both in worms that declined to spin and those that died at moults.

Fourth Brood.

Eggs laid	..	.. 4-VIII to 19-VIII.
Eggs hatched	..	.. 10-VIII to 26-VIII.
Cocoons formed	..	.. 26-VIII to 10-IX.
Moths emerged	..	.. 10-IX to 26-IX.
		37 days.

For this brood, 49,000 eggs by weight were kept ; 100 eggs weigh 2·5 grains. Only 25,000 cocoons were obtained since over 20,000 worms died before or at the first moult, 1,500 died when full-grown, and 1,000 could not spin. To secure the 9½ seers of cocoons, 18

maunds 37 seers of leaf were supplied, giving only 76 maunds of leaf to the maund of silk; there was thus no real loss, estimating from the amount of leaf used.

The following is the detailed record of each day :—

Eggs.	Larvæ hatched.	Pupated.	Emerged.
4 to 19 Aug.	10 to 26 Aug.	26 Aug. to 10 Sept.	10 to 26 Sept.

	Food supplied.			Food wasted.			Excrement.			Dead.	Picked for spinning.	Worms which could not spin among the picked.
	Md.	sr.	ch.	Md.	sr.	ch.	Md.	sr.	ch.			
14-VIII	0	5	14	0	0	6		..				..
15-VIII	0	7	0	0	1	8		..		..	..	..
16-VIII	0	5	12	0	4	0		..		..	..	..
17-VIII	0	6	4	0	3	8		..		..	..	..
18-VIII	0	7	0	0	3	0		..		21	..	..
19-VIII	0	11	14	0	2	0				25	..	..
20-VIII	0	18	0	0	2	0	0	0	13	30	..	..
21-VIII	0	22	0	0	3	8	0	1	8	22	..	..
22-VIII	0	21	0	0	4	0	0	2	0	33	..	..
23-VIII	0	26	0	0	5	8	0	4	0	40	..	..
24-VIII	1	6	0	0	3	0	0	5	0	50	..	..
25-VIII	1	12	0	0	3	8	0	5	8	95	..	..
26-VIII	1	24	0	0	1	8	0	6	12	80	1,200	..
27-VIII	2	0	0	0	12	0	0	20	8	74	2,400	..
28-VIII	1	13	8	0	22	0	0	14	0	54	5,000	..
29-VIII	1	8	8	0	12	0	0	18	0	73	5,200	10
30-VIII	0	32	0	0	10	0	0	6	0	81	2,000	65
31-VIII	0	36	0	0	4	0	0	8	0	78	1,000	
1-IX	0	38	8	0	6	0	0	7	0	86	300	
2-IX	1	12	12	0	4	2	0	12	4	83	500	73
3-IX	0	36	0	0	7	8	0	15	2	91	1,600	21
4-IX	0	21	0	0	7	12	0	13	8	35	2,400	314
5-IX	0	19	0	0	5	8	0	11	0	25	2,100	111
6-IX	0	6	0	0	4	2	0	4	0	22	800	56
7-IX	0	2	8	0	1	3	0	0	12	15	260	25
8-IX	0	0	12	0	3	0	0	0	8	19	125	10
9-IX	0	0	6	0	0	3	0	0	2	5	60	18
10-IX	0	0	0							11		

Fifth Brood.

Eggs laid	.. ..	13-IX	to	26-IX.
,, hatched	.. ..	20-IX	to	3-X.
Cocoons formed	.. ..	5-X	to	26-X.
Moths emerged	.. ..	21-X	to	16-XI.

To this brood about fifty maunds of leaf were given, about 76,000 cocoons were obtained, but about 45,000 worms died, 30,000 just before pupation; this was due to overcrowding, as an attempt was being made to get as large a brood as the rearing house could take, and secondly, to the difficulty of getting food,

as it had to be collected from villages miles away, was hours on the road and could only be got twice a day. Overcrowding, lack of attention, irregular feeding and fermenting food played havoc with the worms and the cocoons only weighed 4,000 to the seer.

The detailed record is as follows :—

Eggs 13 to 26 Sept. Hatched 21 Sept. to 3 Oct. Pupated 5 to 26 Oct. Moths 21 Oct. to 16 Nov.

Date.	Food supplied.			Food wasted.			Excrement.			Dead.	Picked for spinning.	
	Md.	sr.	ch.	Md.	sr.	ch.	Md.	sr.	ch.			
23-IX	0	2	8		..			..		10	....	
24-IX	0	3	0	0	0	8		..		25	....	
25-IX	0	10	8	0	2	0		..		85	....	
26-IX	0	14	2	0	1	14	0	1	2	95	....	
27-IX	0	28	12	0	3	8	0	2	2	51	....	
28-IX	0	35	8	0	7	0	0	2	4	31	....	
29-IX	0	38	4	0	8	8	0	4	2	49	....	
30-IX	1	14	4	0	6	8	0	17	0	85	....	
1-X	1	32	0	0	7	12	0	20	4	96	....	Up to this date leaves were got from the $\frac{3}{4}$ acre plot.
2-X	2	1	12	0	5	8	0	25	0	112	....	
3-X	2	26	8	0	4	8	0	28	4	..	....	
4-X	2	36	4	0	5	4	0	34	12	145	....	
5-X	2	21	4	0	3	0	0	31	0	200	800	
6-X	1	3	0	0	2	12	0	22	12	221	5,400	
7-X	2	12	0	0	3	4	0	33	4	261	8,850	
8-X	1	28	0	0	5	12	0	14	12	382	3,000	
9-X	1	30	0		..			..		2,600	2,250	
10-X	1	20	0		..			..		4,080	2 200	
11-X	1	20	0	0	6	0	0	11	0	2,370	500	
12-X	1	20	0	0	8	0	0	13	0	200	500	
13-X	1	26	0	0	6	8	0	16	12	356	150	
14-X	1	30	0	0	6	0	0	16	0	394	....	
15-X	2	17	0	0	3	0	0	17	0	276	65	
16-X	2	0	0	0	5	0	0	20	2	643	820	
17-X	2	2	0	0	2	0	0	26	8	605	3,500	
18-X	1	20	0	0	4	0	0	16	6	590	5,300	
19-X	1	10	0	0	3	0	0	11	0	600	5,300	
20-X	1	20	0	0	4	0	0	15	0	1,500	2,900	
21-X	2	31	0	0	7	0	0	15	0	2,510	2,000	
22-X	1	22	0	0	31	0	0	21	0	6,200	2,100	
23-X	1	5	0	0	18	0	0	16	0	5,000	2,900	
24-X	0	32	0	0	22	0	0	12	0	3,960	3,100	
25-X	0	26	0	0	16	0	0	8	0	5,235	1,300	

Sixth Brood.—There being little castor available, small broods were kept, and an attempt was made to space them out so that there should be always some in all stages, and not immense numbers in one stage, all requiring immense quantities of food at once as they got mature.

	Eggs laid.	Eggs hatched.	Cocoons formed.	Moths emerged.
(1)	23-X	1-XI	27-XI to 2-XII	*9 to 16-1-08
(2) & (3)	2-XI*	9-XI	10 to 22-XII	*17 to 28-1
(4)	9-XI	22-XI	8 to 26-I	28-II (first)
(5)	14 to 22-XI	28-XI to 9-XII	26-1 to 3-II.	10-III (first)

Date.	Food supplied.			Leaves wasted.			Excrement.			Dead.	How many picked for spinning.
	Md.	sr.	ch.	Md.	sr.	ch.	Md.	sr.	ch.		
2-XI	0	0	1								
3-XI	0	0	1		..			..		2	
4-XI	0	0	1		..			..		2	
5-XI	0	0	2		..			..		3	
6-XI	0	0	2		..			..		4	
7-XI	0	0	3		..			..		6	
8-XI	0	0	3		..			..		18	
9-XI	0	0	3		..			..		4	
10-XI	0	0	4		..			..		2	
11-XI	0	0	4		..			..		4	
12-XI	0	0	4		..			..		4	
13-XI	0	0	4½	0	0	1		..		11 (4 cut by	
14-XI	0	0	4½	0	0	2		..		something).	
										3	
15-XI	0	0	4½	0	0	1½		..		1	
16-XI	0	0	7	0	0	1½	0	0	½	..	
17-XI	0	0	8	0	0	1½	0	0	½	2	
18-XI	0	0	13	0	0	½	0	0	½	2	
19-XI	0	0	7		..		0	0	1½	..	
20-XI		..			..			..		3	
21-XI	0	0	7	0	0	2	0	0	1	1	
22-XI	0	1	3	0	0	2	0	0	1	..	
23-XI	0	1	12	0	0	8	0	0	4	1	
24-XI	0	2	4	0	0	9	0	0	5½	3	
25-XI	0	1	8	0	0	3	0	0	5	..	
26-XI	0	1	12	0	0	3¼	0	0	6	4 could not	100
27-XI	0	1	14	0	0	5	0	0	9	moult.	
										..	265
28-XI	0	1	10	0	0	5½	0	0	11	..	216
29-XI	0	0	9	0	0	6	0	0	4½	..	57
30-XI	0	0	3½	0	0	3½	0	0	1¾	1	24
1-XII	0	0	1	0	0	1½	0	0	½	1 cut by	6
2-XII	0	0	½		..			..		something.	
										11 missed.	
3-XII		..			..			..			
TOTAL	0	18	½	0	3	8¾ 0	0	3	4¼		

674 cocoons in all :

6 sent to I. E.; they also spun.

2 could not spin.

* These were artificially hurried by heating in a closed moist chamber. 77 seers of leaf were supplied and 1 seer of cocoons secured; the detailed records are attached.

Moths (except 81) emerged by heating between 9 and 16-I-08. Three cocoons spun on 1-XII were kept separate and not heated. Moths came out from these between 21 to 24-I-08.

1,000 eggs kept by weight. Laid 2 Nov. Hatched 9 Nov. 119 did not hatch.

Date.	Food supplied.			Food wasted.			Excrement.			Dead.	How many picked for spinning.
	Md.	sr.	ch.	Md.	sr.	ch.	Md.	sr.	ch.		
9-XI	0	0	1		..			..		..	
10-XI	0	0	1		..			..		..	
11-XI	0	0	2		..			..		9	
12-XI	0	0	2		..			..		12	
13-XI	0	0	2	0	0	½		..		8	
14-XI	0	0	2	0	0	½		..		13	
15-XI	0	0	2	0	0	½		..		23	
16-XI	0	0	2	0	0	½		..		16	
17-XI	0	0	2	0	0	½		..		18	
18-XI	0	0	2½	0	0	½		..		14	
19-XI	0	0	1	0	0	½		..		1	
20-XI	(2nd moult)				..			..		..	
21-XI	0	0	2	0	0	½	0	0	½	12	
22-XI	0	0	3	0	0	⅓	0	0	⅓	4	
23-XI	0	0	3	0	0	½	0	0	¾	4	
24-XI	0	0	3	0	0	½	0	0	¼	..	
25-XI	(3rd moult).				..			..		2	
26-XI	0	0	3	0	0	¼		..		5	
27-XI	0	6	0	0	0	½	0	1		..	
28-XI	0	0	10	0	0	1	0	0	10	4	
29-XI	0	0	9	0	0	1	0	0	2½	2	591 counted living to-day.
30-XI	0	0	1	0	0	1½	0	0	¾		
1-XII	0	0	1		..			..		4th moult.	
2-XII	0	0	6	0	0	2½	0	0	½	..	
3-XII	0	0	13	0	0	2	0	0	½	23 destroyed.	568 counted living; rest cut & eaten by rats.
4-XII	0	1	0	0	0	3½	0	0	1	5 missing.	
5-XII	0	0	13	0	0	1½	0	0	1½	2 missing.	4 sent to office as diseased living.
6-XII	0	1	0	0	0	2½	0	0	2½	1	
7-XII	0	1	4	0	0	2½	0	0	4	..	
8-XII	0	1	4	0	0	2½	0	0	4	1	
9-XII	0	1	4	0	0	3½	0	0	1	..	
10-XII	0	1	4	0	0	4	0	0	8½	2 rat cut.	18 : 554 living
11-XII	0	1	4	0	0	3	0	0	7	2	173
12-XII	0	0	10	0	0	2	0	0	3	..	147
13-XII	0	0	3	0	0	1	0	0	½	5	74
14-XII	0	0	2	0	0	½	0	0	½	1	24
15-XII	0	0	2	0	0	½	0	0	½	2	10
16-XII	0	0	1½	0	0	½	0	0	¼	15	6
17-XII	0	0	1½	0	0	¾	0	0	¼	..	15
18-XII	0	0	1½	0	0	½	0	0	¼	5	5
19-XII	0	0	¾	0	0	¼	0	0	⅛	4	4
20-XII	0	0	¾	0	0	¼	0	0	⅛	4	5
21-XII	0	0	½	0	0	¼		..		8	4; 20 counted living.
22-XII	0	0	¼	0	0	⅛		..		3	
23-XII	0	0	⅛		..			..		3	
24-XII		..			..			..		2	
25-XII		..			..			..		6	

1,000 eggs aid 2 Nov.—kept by counting. Hatched 9 Nov. 89 did not hatch.

Date.	Food supplied.			Food wasted.			Excrement.			Dead.	Picked for spinning.	Remarks.
	Md.	sr.	ch.	Md.	sr.	ch.	Md.	sr.	ch.			
9-XI	0	0	1		..			..		..	..	
10-XI	0	0	1		..			..		..	..	
11-XI	0	0	2		..			..		..	..	
12-XI	0	0	2		..			..		1	..	
13-XI	0	0	2	0	0	½		..		4	..	
14-XI	0	0	2	0	0	½		..		3	..	
15-XI	0	0	2	0	0	½		..		3	..	
16-XI	0	0	2¼	0	0	½		..		6	..	
17-XI	0	0	2	0	0	½		..		10	..	
18-XI	0	0	2½	0	0	½		..		5	..	Second moult.
19-XI	0	0	1½	0	0	½		..		6	..	
20-XI		..			..			..		..	..	
21-XI	0	0	2	0	0	½	0	0	½	6	..	
22-XI	0	0	3	0	0	⅓	0	0	⅓	6	..	
23-XI	0	0	3½	0	0	½	0	0	¾	1	..	Third moult.
24-XI	0	0	5	0	0	1	0	0	½	..	..	
25-XI		..			..			..		..	..	
26-XI	0	0	2		..			..		9	..	
27-XI	0	0	7	0	0	1½	0	0	½	1	..	
28-XI	0	0	12	0	0	1¼	0	0	1¼	2	..	Fourth moult.
29-XI	0	0	15	0	0	2	0	0	1¾	4	..	
30-XI	0	0	1	0	0	2½	0	0	1½	..	..	
1-XII	0	0	1½		..			..		..	..	
2-XII	0	0	5½	0	0	1½	0	0	½	2	..	
3-XII	0	0	13	0	0	1½	0	0	½	2 cut by rat.	..	
4-XII	0	1	0	0	0	3	0	0	1	..	..	
5-XII	0	1	0	0	0	2½	0	0	1½	29 cut 1 dead.	..	704 counted living.
6-XII	0	1	0	0	0	3½	0	0	3	33 cut 4 dead.	..	679 ,, ,,
7-XII	0	1	8	0	0	4½	0	0	3	21 cut 4 dead.	..	666 ,, ,,
8-XII	0	1	8	0	0	5½	0	0	3	11 cut 2 dead.	..	654 ,, ,, Rats poisoned.
9-XII	0	1	8	0	0	5	0	0	3¾	12 cut	..	
10-XII	0	1	8	0	0	4½	0	0	7	4 cut	..	
11-XII	0	1	4	0	0	4	0	0	5½	..	26	
12-XII	0	0	15	0	0	4	0	0	5	1 dead	159	
13-XII	0	0	6	0	0	2	0	0	1	3	205	
14-XII	0	0	3	0	0	1	0	0	½	..	67	
15-XII	0	0	3	0	0	1	0	0	½	..	39	
16-XII	0	0	2	0	0	½	0	0	¼	..	17	
17-XII	0	0	2	0	0	½	0	0	¼	2	15	
18-XII	0	0	2	0	0	¾	0	0	¼	1	36	
19-XII	0	0	1	0	0	½	0	0	¼	..	14	
20-XII	0	0	¾	0	0	¼	0	0	⅛	1	4	
21-XII	0	0	½	0	0	¼		..		2	8	
22-XII	0	0	¼	0	0	⅛		..		..	7	
23-XII	0	0	⅛		..			..		..	..	
24-XII		..			..			..		1	..	
25-XII		..			..			..		2	..	

2,000 eggs kept (by weight). Laid 9 Nov. Hatched night 22 Nov.

Date.	Food supplied.			Food wasted.			Excrement.			Dead.	Picked for spinning.	REMARKS.
	Md.	sr.	ch.	Md.	sr.	ch.	Md.	sr.	ch.			
23-XI	0	0	½	..				..		..	....	
24-XI	0	0	1	0	0	¼		..		..	....	
25-XI	0	0	1½	0	0	½		..		..	....	
26-XI	0	0	1½	0	0	½		..		..	....	
27-XI	0	0	1½	0	0	½		..		..	....	
28-XI		..		..				..		..	....	First moult.
29-XI		..		..				..		..	....	
30-XI	0	0	1	..				..		..	....	
1-XII	0	0	1½	0	0	½		..		1	....	
2-XII	0	0	1½	0	0	¾		..		..	....	531 counted living.
3-XII	0	0	2	0	0	½		..		..	....	
4-XII	0	0	4	0	0	¼		..		2	....	
5-XII	0	0	4	0	0	1½		..				
6-XII	0	0	3	0	0	1		..		1	....	
7-XII	0	0	2	0	0	1		..		..	....	
8-XII		..		..				..		..	....	Second moult.
9-XII	0	0	2	0	0	1		..		..	....	
10-XII	0	0	3	0	0	1½	0	0	¼	3	....	
11-XII	0	0	3	0	0	1	0	0	¼	..	....	
12-XII	0	0	4	0	0	1	0	0	¼	..	....	
13-XII	0	0	6	0	0	¾	0	0	¼	..	....	
14-XII	0	0	6	0	0	1½	0	0	½	..	....	
15-XII	0	0	4	0	0	1	0	0	½	4	....	
16-XII		..		..				..		1	....	Third moult.
17-XII	0	0	3	0	0	1¼	0	0	½	..	....	
18-XII	0	0	2	0	0	½	0	0	¼	5	....	512 counted living.
19-XII	0	0	3	0	0	¼	0	0	¼	..	....	
20-XII	0	0	5	0	0	½	0	0	½	..	....	
21-XII	0	0	5	0	0	¼	0	0	½	2	....	
22-XII	0	0	5	0	0	¾	0	0	¾	..	....	
23-XII			..	0	0	3		..		1	....	
24-XII			..	0	0	¾	0	0	¼	..	....	
25-XII			..			..		..		..	....	
26-XII	0	0	1			..		..		..	....	
27-XII	0	0	2			..		..		6	....	
28-XII	0	0	5	0	0	1	0	0	½	..	....	Fourth moult.
29-XII	0	0	6	0	0	1	0	0	¾	8	....	
30-XII	0	0	9	0	0	1½	0	0	1½	..	....	Counts up to moult
31-XII	0	0	12	0	0	1½		..		..	....	
1-I-08	0	0	12	0	0	1½	0	0	1½	3	....	Counts up to moult.
2-I	0	0	12	0	0	1½	0	0	1½	1	....	
3-I	0	0	13	0	0	2	0	0	1½	2	....	
4-I	0	0	15	0	0	2½	0	0	1¼	1	....	
5-I	0	1	0	0	0	3¼	0	0	1¾	..	....	
6-I	0	1	0			2¼	0	0	2¼	..	....	
7-I	0	1	0			3	0	0	2¼	3	....	
8-I	0	1	0	0	0	3½	0	0	2¼	..	8	
9-I	0	0	15	0	0	3½	0	0	2½	..	67	
10-I	0	0	10	0	0	3¼	0	0	2	1	121	
11-I	0	0	8	0	0	4½	0	0	1½	..	102	
12-I	0	0	4	0	0	3	0	0	1	..	73	
13-I	0	0	2	0	0	1	0	0	½	..	39	
14-I	0	0	1	0	0	½	0	0	½	..	15	
15-I	0	0	1	0	0	½	0	0	½	..	9	
16-I	0	0	½	0	0	¼	0	0	¼	..	2	
17-I	0	0	¼	0	0	..		..		..	1	

19-I	12 still living—are full-grown—not eating well, also not spinning probably on account of extreme cold.	
24-I	.. ..	8
25-I	.. ..	2
26-I	.. ..	2

About 550 eggs laid between 14 to 22 Nov. were kept. They hatched between 28 Nov. and 9 Dec. 412 worms were found to be living on 18 Dec., some in the first and some in the second stage.

Date.	Food supplied.			Food wasted.			Excrement.			Dead.	Picked for spinning.	Remarks.
	Md.	sr.	ch.	Md.	sr.	ch.	Md.	sr.	ch.			
18-XII			..			..			..	..	....	412 counted living.
19-XII	0	0	1	0	0	$\frac{1}{8}$	0	0	$\frac{1}{4}$	3	....	
20-XII	0	0	$1\frac{1}{4}$	0	0	$\frac{1}{4}$	0	0	$\frac{1}{8}$	2	....	
21-XII	0	0	$1\frac{1}{2}$	0	0	$\frac{1}{4}$	0	0	$\frac{1}{8}$	4	....	
22-XII	0	0	2	0	0	$\frac{1}{4}$	0	0	$\frac{1}{8}$	2	....	
23-XII	0	0	2	0	0	$\frac{1}{4}$	0	0	$\frac{1}{8}$	3	....	
24-XII	0	0	2	0	0	$\frac{1}{2}$	0	0	$\frac{1}{4}$	4	....	
25-XII	0	0	2	0	0	$\frac{1}{2}$	0	0	$\frac{1}{4}$	4	....	
26-XII	0	0	2	0	0	$\frac{1}{2}$	0	0	$\frac{1}{4}$	..	....	
27-XII	0	0	2	0	0	$\frac{1}{2}$	0	0	$\frac{1}{4}$	5	....	
28-XII	0	0	2	0	0	$\frac{1}{2}$	0	0	$\frac{1}{4}$	..	....	
29-XII	0	0	$\frac{1}{4}$	0	0	$\frac{1}{8}$	0	0	$\frac{1}{8}$	1	....	
30-XII	0	0	$\frac{1}{4}$	0	0	$\frac{1}{8}$	0	0	$\frac{1}{8}$	..	....	
31-XII	0	0	$1\frac{1}{2}$	0	0	$\frac{1}{4}$	0	0	$\frac{1}{8}$	1	....	
1-I	0	0	2	0	0	$\frac{1}{2}$	0	0	$\frac{1}{4}$	..	....	
2-I			2	0	0	$\frac{3}{4}$	0	0	$\frac{1}{4}$	1	....	
3-I	0	0	3	0	0	$\frac{1}{2}$	0	0	$\frac{1}{4}$	1	....	
4-I	0	0	3	0	0	$\frac{3}{4}$	0	0	$\frac{1}{4}$	2	....	
5-I	0	0	4	0	0	1	0	0	$\frac{1}{2}$	1	....	
6-I	0	0	4	0	0	1	0	0	$\frac{3}{4}$	..	....	
7-I	0	0	4	0	0	$\frac{3}{4}$	0	0	$\frac{1}{2}$	2	....	
8-I	0	0	4	0	0	$1\frac{1}{4}$	0	0	$\frac{1}{2}$	1	....	
9-I	0	0	3	0	0	$\frac{1}{4}$	0	0	$\frac{1}{4}$	..	....	Resting for moult.
10-I	0	0	2	0	0	$\frac{1}{2}$	0	0	$\frac{1}{4}$	2	....	
11-I	0	0	$\frac{1}{2}$	0	0	$\frac{1}{2}$	0	0	$\frac{1}{4}$	2	....	
12-I	0	0	2	0	0	$\frac{1}{2}$	0	0	$\frac{1}{2}$	2	....	
13-I	0	0	2	0	0	$\frac{1}{2}$	0	0	$\frac{1}{2}$	1	....	
14-I	0	0	4	0	0	$\frac{3}{4}$	0	0	$\frac{1}{2}$	1	....	
15-I	0	0	4	0	0	1	0	0	$\frac{1}{2}$	2	....	
16-I	0	0	4	0	0	1	0	0	$\frac{1}{2}$	..	....	
17-I	0	0	4	0	0	1	0	0	$\frac{3}{4}$	4	....	
18-I	0	0	4	0	0	1	0	0	$\frac{3}{4}$	2	....	
19-I	0	0	4	0	0	$\frac{1}{2}$	0	0	$\frac{3}{4}$	2	....	
20-I	0	0	4	0	0	1	0	0	$\frac{3}{4}$	..	....	
21-I	0	0	4	0	0	$\frac{1}{2}$	0	0	$\frac{3}{4}$	5	....	
22-I	0	0	4	0	0	$\frac{1}{2}$	0	0	$\frac{3}{4}$	..	....	
23-I	0	0	4	0	0	$\frac{1}{2}$	0	0	$\frac{3}{4}$	..	....	
24-I	0	0	4	0	0	$\frac{1}{2}$	0	0	$\frac{3}{4}$	5	....	
25-I	0	0	9	0	0	$1\frac{1}{2}$	0	0	$1\frac{1}{2}$	5	....	
26-I	0	0	12	0	0	$1\frac{1}{4}$	0	0	2	3	7	
27-I	0	0	12	0	0	$2\frac{1}{4}$	0	0	$2\frac{3}{4}$	4	15	
28-I	0	0	11	0	0	$2\frac{1}{2}$	0	0	$2\frac{1}{4}$	15	37	11 out of the dead could not moult.
29-I	0	0	$7\frac{1}{2}$	0	0	$3\frac{1}{2}$	0	0	$1\frac{1}{2}$	16	41	
30-I	0	0	6	0	0	$1\frac{1}{4}$	0	0	1	9	28	
31-I	0	0	3	0	0	$1\frac{1}{2}$	0	0	5	5	34	
1-XII	0	0	3	0	0	$\frac{1}{2}$	0	0	$\frac{1}{2}$	14	22	
2-XII	0	0	2	0	0	$\frac{1}{2}$	0	0	$\frac{1}{2}$	7	22	
3-XII	0	0	1	0	0	$\frac{1}{4}$	0	0	$\frac{1}{4}$	9	6	
4-XII			..			..			..	9	..	
TOTAL		10	6		2	$6\frac{1}{2}$		1	15	161	212	

33 were thrown away as they were neither eating nor spinning. They were dying gradually. On cutting some of the worms which were dying, masses of undigested food were found in the abdomen. No other symptoms of any disease could be made out.

210 cocoons secured in all—2 could not spin.

Moths began to emerge 10 March.

The first three lots of worms in the sixth brood were given artificial heat in the pupal stage in order to hasten the emergence of the moths. The weather at the time was very cold, with cold winds blowing, and the temperature was as low as between 35°F. to 40°F. The cocoons were kept in a closed chamber in which the temperature was kept up to 80°F. to 100°F., and a high degree of moisture was produced by heating water so that the wet bulb thermometer recorded between 65 to 80. The results are shown below.

Date when the worms spun cocoons.	Date of commencement of the application of the artificial heat.	Date of emergence of moths.	Duration of the pupal stage in days.
27-11-07	7-1-08	9-1-08	43
10-12-07	7-1-08	17-1-08	38
11-12-07	7-1-08	17-1-08	37

Date and hour.	Dry bulb.	Wet bulb.	Per cent. of humidity.	REMARKS.
7-1-08 noon	75	..	..	Started.
„ 1 P.M	81	68	48%	
„ 2 P.M.	81	68	48%	
„ 3 P.M	83	73	60%	
„ 4 P.M.	91	76	48%	
8-1-08 6 A.M.	70	59	48%	
„ 10 A.M.	91	74	42%	
„ 11 A.M.	95	78	44%	
„ 12 noon	96	74	32%	
„ 2 P.M.	100	79	39%	
„ 3 P.M.	96	76	37%	
„ 6 P.M	93	75	40%	Moths emerged night 8-1-08.
9-1-08 7 A.M.	75	65	56%	
„ 10 A.M.	80	70	58%	
„ 1 P.M. to 4 P.M.	90	77	53%	
„ 8 P.M.	80	70	58%	
10-1-08 8 A.M	90	74	44%	
„ 11 A.M.	90	81	66%	
„ 4 P.M.	85	75	61%	
„ 10 P.M	85	75	61%	

Date and hour.	Dry bulb.	Wet bulb.	Per cent. of humidity.	REMARKS.
11-1-08 8 A.M.	80	65	41%	
,, 1 P.M.	80	70	58%	
,, 4 P.M.	85	72	51%	
12-1-08 8 A.M.	80	70	58%	
,, 11 A.M.	85	76	64%	
,, 4 P.M.	85	76	64%	
13-1-08 9 A.M.	78	69	61%	
,, 1 P.M.	84	79	79%	
,, 4 P.M.	84	79	79%	
14-1-08 8 A.M.	83	74	63%	
,, noon	86	76	61%	
,, 4 P.M.	86	76	61%	After this no records were kept for each day but the thermometers were watched so that the dry bulb ranged between 70 and 90 degrees and the wet bulb between 60 and 80 degrees.
24-1-08 Stopped				

To the following no heat was applied and they were allowed to come out in the natural course.

Date when the worms spun cocoons.	Date of emergence of moths.	Duration of pupal stage in days.
1 Dec.	21 Jan.	52
8 Jan.	28 Feb.	51

SEVENTH BROOD—

Eggs laid.	Eggs hatched.	Worms spun.	Moths emerged.
*11 Jan.	4 Feb.	11 Mch.	31 Mch.
*25 Jan.	15 Feb.	20 Mch.	8 Apl.
2 Mch.	15 Mch.	9 Apl.	25 Apl.

In this brood, the effect of the disease on the weakly race is clearly seen; many eggs failed to hatch; many worms died and the results are very poor.

* (The first lots hastened by incubation.)

2,000 eggs laid 11 Jan.—kept by weight. Hatched 4 Feb. 350 did not hatch.

Date.	Food supplied.			Food wasted.			Excrement.			Dead.	Picked for spinning.	REMARKS.
	Md.	sr.	ch.	Md.	sr.	ch	Md.	sr.	ch.			
4-II	0	0	¼		....			....		..		..
5-II	0	0	½		....			....		..		..
6-II	0	0	¾	0	0	¼	0	0	¼	..		..
7-II	0	0	¾	0	0	½	0	0	½	..		..
8-II	0	0	1	0	0	½		....		..		..
9-II	0	0	1	0	0	½		....		15		..
10-II	0	0	1¾	0	0	¾		....		12		..
11-II	0	0	2	0	0	¾		....		12		..
12-II	0	0	2	0	0	½		....		10		..
13-II		....		0	0	1		....		11		..
14-II		....			....			....		8		Moult.
15-II	0	0	½	0	0	½		....		..		..
16-II	0	0	1	0	0	½		....		16		..
17-II	0	0	2	0	0	½		....		10		..
18-II	0	0	3	0	0	½		....		24		..
19-II	0	0	3	0	0	1		....		17		..
20-II		....			....			....		19		Moult.
21-II		....		0	0	1½		....		12		..
22-II	0	0	6	0	0	1¾		....		14		..
23-II	0	0	6	0	0	1½		....		10		..
24-II	0	0	6	0	0	1		....		10		..
25-II	0	0	5		....			....		14		..
26-II		....			....			....		42		Moult. 1,125 counted living.
27-II	0	0	6	0	0	1¾		....		7		
28-II	0	0	9	0	0	1	0	0	¾	5		Contained in one basket 2′ diam. not overcrowded.
29-II	0	0	14	0	0	1	0	0	1¾	..		
1-III	0	0	12	0	0	1½	0	0	2½	16		52 which were lagging behind, rejected.
2-III	0	0	6	0	0	½	0	0	1	52		
3-III	0	0	½		....			....		..		Moult.
4-III	0	0	10	0	0	½	0	0	½	..		
5-III	0	1	0	0	0	2½		....		4		
6-III	0	1	8	0	0	3½		....		6		
7-III	0	2	4	0	0	2½		....		5+83		85 rejected, they were lagging behind, 917 counted left on 7 Mch.
8-III	0	2	4	0	0	3½		....		2		
9-III	0	2	4	0	0	4		....		3	110	
10-III	0	2	8	0	0	3½		....		..	261	
11-III	0	2	0	0	0	4		....		.. 6	215	
12-III	0	1	12	0	1	8		....		8	197	
13-III	0	0	10	0	0	8		....				
14-III	0	0	2½	0	0	4½		....		3+24	41	24 rejected, not spun 5.
15-III		....		0	0	1½		....		1	4	

34,000 eggs laid between 20 to 30 Jan. Hatched between 13 to 18 Feb. About 6,100 did not hatch.

Date.	Food supplied.		Food wasted.		Excrement.		Dead.	Picked for spinning.	REMARKS.
	Sr.	Ch.	Sr.	Ch.	Sr.	Ch.			
13-II	0	¼	0	0	..				
14-II	0	1½	0	0	..				
15-II	0	3	0	0	..				
16-II	0	5¾	0	1½	..				
17-II	0	8¾	0	2½	..				
18-II	0	9¾	0	2½	..				
19-II	0	15	0	3½	..				
20-II	1	8	0	4¼	..				
21-II	1	10	0	4½	..				
22-II	1	2	0	5¾	..				
23-II	0	12	0	5	..				
24-II	1	0	0	8¾	..		41		
25-II	1	5	0	9½	..		62		
26-II	1	15	0	9	..		300		
27-II	2	6	0	12	..		250		
28-II	3	12	0	15	..		121		
29-II	3	7	1	1	..		71		
1-III	3	4	0	10	..		156		
2-III	6	12	0	13	..		146		
3-III	7	9½	1	4	..		40		
4-III	7	8	0	7	..		61		
5-III	7	1	1	0	..		47		Mean percentage humidity at 8 A.M. from 6th to 17th March is 49%.
6-III	12	12	1	6	..		139		
7-III	20	12	1	10	..		30		
8-III	23	2	2	3	..		99		
9-III	20	0	2	4	..		62		
					..				Almost all dying at 3rd moult unable to moult.
10-III	20	0	2	7	..		197		
11-III	20	0	2	8	..		126		
					..				
12-III	25	12	3	12	..		526		Almost all at 3rd moult. Leaves getting dry on account of West winds.
					..				
					..				
					..				
					..				
13-III	45	10	4	6	..		403		
14-III	40	2	7	8	..		131		
15-III	46	10	8	4	..		152		
16-III	55	1	8	10	..		121		
17-III	51	10	13	2	..		83	20	Percentage humidity rose and for next 12 days averaged 61·5%.
18-III	48	8	8	0	..		30	365	
19-III	47	0	10	6	..		97	1,937	
20-III	40	0	12	0	..		57	4,553	
21-III	22	0	6	0	..		97	5,428	
22-III	18	0	12	0	..		..	2,053	
23-III	14	0	5	0	..		63	1,081	
24-III	15	0	4	0	..		63	1,010	
25-III	5	0	3½	0	..		51	695	
26-III	2	8	2½	0	..		49	279	
27-III	1	3	0	10	..		37	197	
28-III	0	10	0	10	..		31	89	
29-III	0	6	0	3	..		59	32	59 rejected : 17,711 cocoons.
30-III	0	2½	0	1	..		36	8	36 rejected.
31-III	..		..		..		..	4	
1-IV	..		..		..		..	6	

408 grains of eggs (100 = 2·8 grs.), 13,750 eggs laid between 2 to 4 Mch. 08. Hatched 15 to 16 Mch. About 300 did not hatch and 400 rejected.

Date.	Food supplied.		Food rejected		Dead.	Picked for spinning.	REMARKS.
	Sr.	Ch.	Sr.	Ch.			
16-III	0	2	..				
17-III	0	2	..				
18-III	0	3	..				
19-III	0	5	..				
20-III	0	6	..		4		
21-III	0	5½	0	1½	140		Moulting.
22-III	0	11½	0	1			
23-III	1	6	0	2½	154		
24-III	0	4	0	2½	21		
25-III	0	10	0	1½	51		Moulting.
26-III	2	½	0	2½	163		
27-III	3	3	0	4	205		
28-III	2	5	0	8½			Moulting.
29-III	4	11	0	14	76		12,625 counted living to-day.
30-III	13	½	0	13½	118		
31-III	13	15	1	8	102		
1-IV	8	3	1	11	126		Moulting.
2-IV	18	0			26		
3-IV	30	0	5	0	270		
4-IV	36	0	6	12	154		
5-IV	39	0	6	8	138		
6-IV	48	9	7	½	166		
7-IV	45	2	9	8	131	672	
8-IV	16	3	11	14	102	3,543	
9-IV	11	0	9	0	92	3,777	
10-IV	8	0	3	0	115	1,122	
11-IV	6	0	3	0	81	437	
12-IV	..		2	0	40	207	
13-IV	..		..		76	208	
14-IV	..		..		17	113	
15-IV	..		..		37	94	
16-IV	..		..		26	46	
17-IV	..		..		31	4	
18-IV	..		..		46		
	..		..		rejected.		

Out of those picked for spinning 295 could not spin cocoons.
Moths began to emerge 24 Apl. 08.
Pierced cocoons secured 1 sr. 10 ch.

There is a practice of keeping the feeding trays with worms piled up one above the other. Feeding the worms in this way is rather convenient at the time when the dry winds blow and dry the leaves very quickly, because when the trays are piled up in this way, the leaves do not get dry so soon. In order to find out whether this has any injurious effect on the health of the worms, 12,000 worms were selected from the third lot in the seventh brood just after they passed out of the 3rd moult ; (1) 6,000 were fed in trays which were kept

piled up ; and (2) 6,000 in trays which were kept separate and open. The results were somewhat better in the first case as will be seen from the figures given below ; because the worms kept more moist and although the trays were piled up, they were not airtight and therefore hardly interfered with the breathing and evaporation from the body of the worms. In the wet season the trays should not be piled up in this way.

	1. 6,000 worms just after the 3rd moult fed in trays kept piled up.		2. 6,000 worms just after the 3rd moult fed in trays kept separate and open.	
Date.	Dead.	Picked for spinning.	Dead.	Picked for spinning.
30-III	29	..	61	..
31-III	24	..	47	..
1-IV	41	..	74	..
2-IV	Moult.	..	Moult.	..
3-IV	79	..	102	..
4-IV	58	..	87	..
5-IV	68	..	70	..
6-IV	70	..	66	..
7-IV	58	576	63	96
8-IV	58	2,292	33	1,251
9-IV	30	1,717	57	2,060
10-IV	48	332	56	790
11-IV	31	94	41	343
12-IV	7	19	28	153
13-IV	18	20	51	83
14-IV	3	..	7	29
15-IV	17	..	11	24
16-IV	13	..	9	7
17-IV	7 rejected.	..	17	2
	Out of these 4,865 cocoons secured. 113 could not spin. 659 dead and rejected. 363 missed.		Out of these, 30 rejected, 4,748 cocoons secured. 132 could not spin. 910 dead and rejected. 210 missed.	

Eighth Brood.

30,000 eggs were laid between 4 Apl. and 10 Apl. About 3,000 hatched between 12 Apl. and 19 Apl., but all the worms died before the first moult.

157,000 eggs were laid between 25 Apl. and 30 Apl. These eggs did not hatch, only 300 weak larvæ being obtained and they died before the first moult. So far as could be ascertained, the causes were the gradual weakening of the previous broods from disease (see below page 65), the injurious effect of the forced emergence of moths by

artificial heat in the previous brood and the hot dry weather, the temperature being up to 110°F. in the shade, the humidity low and a dust-laden west wind blowing, as is usual at this time.

A supply of cocoons (600) was obtained in a village near Palasbari, Kamrup, and brought to Pusa. They were isolated and examined : only 41 moths hatched, all weak and it was found that there were abundant maggots and pupæ of a parasitic Tachinid fly. These were destroyed and the whole consignment burnt. A fresh supply was gathered consisting of 400 newly hatched worms, 2,700 eggs and 70 cocoons. These were isolated and the stock issued from quarantine only after careful examination and in the form only of healthy worms.

Ninth Brood.

2,700 eggs hatched 4 July 08.

They were fed, no record being kept of weights.

Date	Died.		Spun.
7-VII	17	..	
8-VII	25	..	
9-VII	20	..	
10-VII	22	..	
11-VII	34	..	
12-VII	35	..	
13-VII	16	..	
14-VII	33	..	
15-VII	18	89	
16-VII	10	164	327 from the 400 live worms. Moths emerged from 31 July.
17-VII	13	74	
18-VII	20		
19-VII	12		
20-VII	6	995	
21-VII	1	700	2,036 from 2,700 eggs. Moths emerged from 6 Aug. 08.
22-VII	4	252	
23-VII	..	63	
24-VII	..	26	

Tenth Brood.

In this brood four separate lots of eggs were kept and in all about 20,700 worms hatched out of the eggs. In all 16,148 cocoons were obtained.

The following are the detailed records. When the worms were made to spin, they got mixed up.

6,000 eggs of moths from white cocoons.
Laid 3 to 4 Aug. Hatched from 10 Aug. About 1,000 eggs did not hatch.

Date.	Approximate No. of worms being fed.	Dead.	Food supplied.	Food rejected.	Picked for spinning.	REMARKS.
			Sr. Ch.	Sr. Ch.		
12-VIII	5,000	30				First moult.
13-VIII	5,000	18	..	..	..	
14-VIII	4,950	28	..	..	..	
15-VIII	..	..	..	..	..	Second moult. These dead are all from the time of 1st moult. They were kept to see if they could revive.
16-VIII	..	..	..	..	..	
17-VIII	4,560	390	..	..	..	
18-VIII	4,529	31	..	..	..	
19-VIII	..	..	..	..	..	
20-VIII	4,403	126	..	..	..	
21-VIII	..	..	..	..	..	About half of the dead could pass the 1st moult.
22-VIII	4,369	34	2 12	..	..	
23-VIII	4,345	24	9 4	..	..	
24-VIII	4,333	12	13 0	1 9	..	
25-VIII	4,303	30	13 3	3 0	..	
26-VIII	4,279	26	10 2	5 8	63	
27-VIII	4,237	42	6 7	1 6	1,544	
28-VIII	4,230	7	0 12	4 5	824	
29-VIII	4,219	11	0 6	0 5	150	
30-VIII	..	6	0 4	0 2	100	
31-VIII	..	2	..	0 1	68	
1-IX	..	3	..	..	14	
2-IX	..	..	..	..	4	Moths began to emerge 10 Sept.

Actually 2,780 cocoons were got.

6,000 eggs of moths from white cocoons.
Laid 7 Aug. Hatched 14 Aug. 08. About 1,300 did not hatch.

Date.	Approximate No. of worms being fed.	Dead.	Food supplied.	Food rejected.	Picked for spinning.	REMARKS.
17-VIII	4,700		Sr. Ch.	Sr. Ch.	..	Moulting.
18-VIII	..	25	..	..	..	
19-VIII	..	..	..	..	..	
20-VIII	..	..	..	..	..	Moult.
21-VIII	4,250	430	..	..	..	Dying mainly at moults.
22-VIII	4,175	75	3 0	..	..	
23-VIII	4,163	12	7 15	1 4	..	
24-VIII	4,132	31	9 8	2 3	..	
25-VIII	4,096	36	6 15	1 14	..	
26-VIII	4,042	54	16 3	2 8	..	
27-VIII	3,977	65	18 11	2 4	..	
28-VIII	3,962	15	39 5	3 5	..	
29-VIII	3,937	25	26 10	7 6	1,518	
30-VIII	..	12	18 8	7 13	2,314	
31-VIII	..	7	7 0	2 4	1,132	
1-IX	..	3	4 8	3 8	350	
2-IX	..	10	1 8	2 11	228	
3-IX	..	7	0 11	0 14	80	5,624
4-IX	..	4	0 1	0 6	24	5,684
5-IX	..	..	..	..	..	
6-IX	..	..	..	..	..	

Actually 5,582 cocoons were got and 64 could not spin.

7,000 eggs from moths from brown cocoons.

Laid 8 to 10 Aug. 08. Began to hatch 15 Aug. All hatched.

Date.	Approximate No. of worms being fed.	Dead.	Food supplied.	Food rejected.	Picked for spinning.	REMARKS.
			Sr. Ch.	Sr. Ch.		
19-VIII	..	..			..	Moulting.
20-VIII	..	..	..	..	..	
21-VIII	..	137	..	..	..	Dead mainly those which could not moult.
					..	
					..	
22-VIII	..	113	1 7	..	..	
23-VIII	..	33	2 14	0 8	..	
24-VIII	..	40	3 14	0 10	..	
25-VIII	..	8	4 15	1 3	..	
26-VIII	..	51	3 10	0 16	..	
27-VIII	..	115	10 7	0 14	..	
28-VIII	..	8	11 5	2 4	..	
29-VIII	..	24	10 6	2 4	..	
30-VIII	..	10	19 3	3 14	37	
31-VIII	..	6	10 0	3 5	1,345	
1-IX	..	4	7 5	4 5	1,600	
2-IX	..	4	1 1	4 4	644	
3-IX	..	1	0 12	0 10	84	3,710
4-IX	..	5	..	0 11	28	3,738
5-IX	..	..	..	..		
	..	..				

Actually 3,530 cocoons were got and 68 could not spin.

5,000 eggs of moths from white cocoons.

Laid 13 Aug. 08. Began to hatch 21 Aug. About 1,000 did not hatch.

Date.	Approximate No. of worms being fed.	Dead.	Food supplied.	Food rejected.	Picked for spinning.	REMARKS.
	Md. sr. ch.	..	Md. sr. ch.	Md. sr. ch.	..	
25-VIII	..	..	0 0 10	..	..	
26-VIII	..	132	0 0 12	0 0 3	..	
					..	Dead ones are mostly those which were lagging behind and are therefore rejected.
					..	
					..	
					..	
	..	..	..	..	..	
27-VIII	..	138	0 2 4	0 0 3	..	
28-VIII	..	9	0 3 9	0 0 10	..	
29-VIII	..	35	0 4 8	0 0 11	..	
30-VIII	..	13	0 6 8	0 0 13	..	
31-VIII	..	20	0 8 6	0 0 15	..	
1-IX	..	12	0 12 4	0 1 3	..	
2-IX	..	9	0 16 6	0 2 6	..	
3-IX	..	17	0 11 11	0 2 13	568	
4-IX	..	18	0 5 0	0 3 4	1,032	
5-IX	..	..	0 2 3	0 1 8	750	
6-IX	..	..	..	0 0 12	..	2,350

Actually 2,350 cocoons were got and 18 could not spin.

Eleventh Brood.

Eggs kept—

25,000	laid	13 to 15 Sept. 08.
40,000	,,	14 to 16 Sept. 08.
30,000	,,	17 Sept.
31,000	,,	18 ,,
22,000	,,	19 ,,
23,000	,,	20 ,,
7,000	,,	21 ,,
178,000		

Began to hatch 21 Sept. 08

,, ,, spin 6 Oct. 08.

Moths began to emerge 25 Oct. 08.

Such a large number of worms was purposely kept in this brood for using up the castor leaves. The worms could not be accommodated in the silkworm house, therefore a part of the potato storage house was used.

In this brood were secured—

Pierced cocoons, 34 srs. 6 ch.
Unpierced ,, 11 ,, 4 ,,

About 3,500 pierced cocoons made up a seer, and unpierced cocoons 1,800. Therefore about 140,550 worms were reared.

Twelfth Brood.

Two lots were reared in this brood. The detailed records are given below—

27 Oct. 15,000 eggs laid
Hatched 6 Nov.

Spun	10 Dec.	90
	11 ,,	866
	12 ,,	1,716
	13 ,,	1,520
	14 ,,	760
	15 ,,	450
	16 ,,	248
	17 ,,	125
	18 ,,	78
	19 ,,	40
	20 to 6 Dec.	100
	23 to 25 ,,	200
		6,193

In this lot many worms were eaten by rats. Also when it became cold, the worms died in the same manner as last year, *viz.*, they

could not moult properly and died. The skins could not be shed and usually remained encircling the last segments.

Moths began to emerge 16 Jan. 09 to 4 Feb. 09.

Eggs laid 14 Nov. Hatched 26 Nov. 08.

Date.	Leaves supplied.			Dead.		
	Md.	sr.	ch.			
26-XI-08		..	..	..		Hatched. The counts in this lot were not kept from the beginning.
24-XII-08	0	0	13	58		
25-XII	0	0	12	156		
26-XII	0	0	13	62		3,340 counted living on this date.
27-XII	0	0	9	37		
28-XII	0	0	12	25		
29-XII	0	0	14	11		
30-XII	0	1	0	28		
31-XII	0	1	1	7		
1-I-09	0	1	14	21		
2-I	0	1	13	28		
3-I	0	2	8	16		
4-I	0	0	8	12		
5-I	0	2	6	17		
6-I	0	1	14	13		
7-I	0	1	13	12		
8-I	0	2	5	16		
9-I	0	2	10	15		
10-I	0	2	13	18		
11-I	0	2	2	5		
12-I	0	4	2	25		
13-I	0	4	3	40		
14-I	0	7	10	66		
15-I	0	9	6	35	10 spun.	
16-I	0	8	10	63	126 "	
17-I	0	7	14	37	252 "	
18-I	0	6	10	25	150 "	
19-I	0	5	12	50	130 "	
20-I	0	3	4	72	342 "	
21-I	0	2	5	110	198 "	
22-I	0	1	8	120	125 "	
23-I	0	0	9	155	50 "	
24-I	0	0	6	52	12 "	
25-I	0	0	4	10	4 "	

Twenty-five living—lived on for some time—were neither eating nor spinning. All died.
Moths began to emerge 24 Feb. 09.

THIRTEENTH BROOD.

It has been seen that intense cold (like intense heat) weakens the worms, and as they feed for a very long period in winter they are more liable to disease than in summer. Just after the winter a period of very dry hot weather follows and the effect on the worms is very bad. This bad effect is noticeable in the first lots reared in this brood. In

order to revive the stock, therefore, a fieldman was sent to Assam to procure some more seed in March 1909. He came back with about 20,000 eggs and eighty seed cocoons. The eggs were not so good and hatched very unsatisfactorily, only about 1,500 worms hatching out in all. The seed cocoons were very good this time and not diseased or flimsy like those got previously. About 1,000 eggs were got from worms reared at Nagpur. The Pusa stock and that got from Assam were reared in separate lots, and it remained to be seen whether the weakened race would revive itself with the fall of rain.

Thirteenth Brood.—9,000 eggs laid .. 20 Jan. 09. Hatched 9 Feb.; 21 ,, ,, 11 ,,; 23 ,, ,, 14 ,,; 7,000 hatched 20 Feb.
30,000 ,, ,, 23 ,, ,, 16 ,,

Date.	Food supplied.	Food wasted.	Excrement.	Dead.	Picked for spinning.	REMARKS.
	Sr. Ch.	Sr. Ch.	Sr. Ch.			
16-II	..	..	..	40	..	
17-II	..	..	..	78	..	
18-II	..	..	..	75	..	
19-II	0 15	..	..	51	..	
20-II	1 6	0 4	..	110	..	
21-II	0 12	0 4	..	88	..	
22-II	..	..	..	..	..	
23-II	..	..	..	..	..	
24-II	..	..	..	..	..	
25-II	0 12	0 6	..	172	..	
26-II	0 12	0 8	..	4,552	..	
27-II	0 15	0 8	..	12,570	..	Percentage humidity fell below 50, and the average to the first week of April was under 40, see records below.
28-II	1 1	0 10	..	6,725	..	
1-III	1 3	0 9	..	4,910	..	
2-III	1 2	0 12	..	95	..	
3-III	1 4	0 14	..	15	..	
4-III	0 14	0 8	..	12	..	
5-III	1 8	0 11	..	90	..	
6-III	1 13	0 7	..	114	..	
7-III	1 12	0 8	..	110	..	
8-III	2 1	0 9	..	75	..	
9-III	2 9	0 11	..	68	..	The average percentage humidity for March was 33 per cent. (taken at 8 A.M.)
10-III	3 2	0 13	..	34	..	
11-III	3 6	1 1	..	53	..	
12-III	2 7	0 6	..	35	..	

Date.	Food supplied.	Food wasted.	Excrement.	Dead.	Picked for spinning	REMARKS.
13-III	1 12	0 12	..	26	..	
14-III	2 5	0 6	..	17	..	
15-III	3 6	0 6	..	34	..	
16-III	3 10	0 11	..	28	..	
17-III	6 2	2 4	..	24	..	
18-III	7 8	2 2	..	109	49	
19-III	9 0	2 12	..	35	168	
20-III	5 5	2 14	..	25	354	
21-III	5 0	1 8	..	25	290	
22-III	4 7½	1 4	..	14	185	
23-III	3 0	1 8	..	30	330	
24-III	2 0	0 12	..	12	161	
25-III	1 8	0 12	..	20	92	
26-III	0 12	0 3½	..	30	76	
27-III	0 8	0 3	..	25	52	
28-III	0 8	0 3	..	8	31	
29-III	0 5	0 3	..	10	24	
30-III	0 4	0 1½	..	11	24	
31-III	..	..	..	..	..	
22,800 eggs laid 1 to 4 Mch. 09. Hatched 12 to 15 Mch. 09. (About 12.000 failed to hatch.)						
28-III	0 8	0 4	..	108	..	
29-III	1 0	0 6	..	150	..	
30-III	1 3	0 5	..	42	..	
31-III	0 14	0 4	..	40	..	
1-IV	1 8	0 5	..	36	..	
2-IV	1 12	0 6	..	34	..	
3-IV	4 0	1 2	..	24	..	
4-IV	4 3	1 3	..	16	..	
5-IV	4 13	0 12	..	20	..	
6-IV	4 5	0 12	..	8	..	
7-IV	5 0	1 8	..	11	..	
8-IV	7 0	1 10	..	8	..	
9-IV	7 6	1 4	..	12	..	
10-IV	8 0	1 10	..	10	169	
11-IV	8 3	1 8	..	13	734	
12-IV	7 0	1 10	..	20	586	
13-IV	4 0	0 11	..	15	275	
14-IV	3 0	0 10	..	11	300	
15-IV	2 0	0 6	..	18	165	
16-IV	0 8	0 3	..	16	45	
17-IV	0 4	..	..	8	50	
18-IV	0 3	..	..	6	48	
19-IV	..	..	..	5	11	
20-IV	..	..	..	..	21	
21-IV	..	..	..	..	15	
22-IV	..	..	..	..	10	
					2,429	cocoons.

Moths began to emerge 28 Apl. 09.

FOURTEENTH BROOD.

36,000 eggs laid 3 May 09. Hatched 10 May 09. (90 per cent. hatched.)

1st Moult 12th May.
2nd „ 14th, 15th May.
3rd „ 18th, 19th „
4th „ 21st, 22nd „

Brought forward.

Spinning—	5,700	27th May.
	8,350	28th ,,
	3,400	29th
	3,050	30th ,,
	1,272	31st ,,
	346	1st June.
	170	2nd ,,
	100	3rd ,,
	60	4th ,,
	20	5th ,,
Total	22,468	

Weight of pierced cocoons, 7 seers 9 ch.; 30 per cent. worms died, of which 800 at and 2,800 after second moult. Average temperature, maximum in shade for May 1909, 102·6, humidity 64 per cent. This brood was from the stock that had come through the cold weather and previous rains.

Fifteenth Brood.

165,000 eggs kept. 90 per cent. hatched.

There was a very serious shortage of leaf, and leaf was brought many miles and in irregular quantity.

Eggs laid 14th to 18th June.

,, hatched 22nd, 23rd, 24th June.

Spinning began 7th July.

The mortality on eight consecutive days of spinning was—

Date.	No. dead.	No. spun.
7th July	11,740	140
8th ,,	10,991	3,300
9th ,,	10,800	7,700
10th ,,	10,999	10,800
11th ,,	10,750	8,300
12th ,,	8,000	10,250
13th ,,	4,500	4,800
14th ,,	3,300	6,300
15th ,,	1,500	4,250

In all—79,245 died, 68,340 spun.

The deaths were due to inability to spin at the proper time owing to insufficient food during the last stage.

SIXTEENTH BROOD.

Eggs laid 27th July to 4th August.

Eggs hatched 2nd August to 11th August.

Worms spun 17th to 25th August.

Of 26,000 worms hatched, 23,973 spun cocoon.

New (M) Brood.—A second lot was started with outside seed—

Eggs laid 19th July.

,, hatched 25th July.

Worms spun 10th August.

Of 4,500 hatched, 4,242 spun cocoons.

New (B) Brood.—Eggs laid 23rd to 26th July.

,, hatched 29th July to 1st August.

Worms spun from 13th August.

Of 30,000 hatched, 28,206 spun.

SEVENTEENTH BROOD.

Eggs laid 16th September.

Eggs hatched	23rd September.
1st Moult	25th ,,
2nd ,,	27th ,,
3rd ,,	30th ,,
4th ,,	3rd October.
Spun	7th ,,

Of 24,000 worms, 64 per cent. died, and 8,700 spun. There was an outbreak of disease.

Second M. Brood.—Eggs laid 29th to 31st August.

,, hatched 5th to 7th September.

1st Moult	7th September.
2nd ,,	10th ,,
3rd ,,	13th ,,
4th ,,	16th ,,
Spun	19th ,,

Of 30,000 worms, 26,727 spun cocoons.

Second B. Brood.—Eggs laid 7th September.

,, hatched	13th ,,
1st Moult	15th ,,
2nd ,,	19th ,,
3rd ,,	22nd ,,
4th ,,	25th ,,
Spun	27th onwards.

Of 18,000 hatched worms, 16,655 spun cocoons.

Third M. Brood.—Eggs laid 9th October.

,, hatched	16th	,,
1st Moult	18th	,,
2nd ,,	21st	,,
3rd ,,	25th	,,
4th ,,	29th	,,

Spinning began 2nd November.

Of 22,500 worms hatched, 15,234 spun cocoons.

After this brood no definite records of this kind were kept and the worms have continued in regular broods; owing to the distribution of seed and the mixing of other seed, the course of the regular broods has not been kept up, and we have three or four broods going on at once. The biggest single brood reared has been one of about 150,000, and that is the full capacity of the rearing house.

Labour for Rearing.

From April 1907 to December 1908 (21 months), about 100 seers of pierced cocoons were produced. For producing this quantity of silk there have been absolutely necessary about 950 cooly days (including care of eggs, rearing of the worms, cleaning and sorting of the cocoons and plucking leaves from plots near by; excluding getting leaves from other villages and a night watchman if separately necessary).

With this may be compared the figures of the two big broods reared at Pusa (including and excluding the items as in the above).—

(1). For one brood occupying 69 days from the first day of oviposition till the cleaning and sorting of the pierced cocoons, and yielding about 19 seers of pierced cocoons; absolutely necessary, 240 cooly days. In this brood the mortality was unusually high at the time of spinning; had it not been for this about 30 seers of cocoons would have been secured.

(2). The second brood occupied about 79 days; yielded about 1 maund of pierced cocoons. Absolutely necessary, about 300 cooly days.

DISEASE, INFLUENCE OF CLIMATE, ETC.

Before discussing this point, we may recapitulate briefly the experience obtained at Pusa with individual broods. The first brood was from the 31st March to 14th May; it was healthy and did well; it must be noted that the seed was direct from Assam. The next brood was from 14th May to about 24th June. The cocoons were small but the worms and moths healthy. The third brood was from the end of June to the 10th August; about 5 per cent. of moths did not emerge, and 3 per cent. died. The cocoons were larger. The fourth brood carried on into September and 40 per cent. of worms died before the first moult, 3 per cent. at maturity and 2 per cent. failed to spin. The fifth brood went on into November and nearly 60 per cent. of the worms died, while there was very great overcrowding, and the leaf was brought long distances as none was available. The cocoons were also small and poor (usually they are large at this season). The next went through the cold months; to get eggs, the cocoons were artificially kept warm. The brood from these eggs was bad, 12 per cent. of the eggs not hatching, and only about fifty per cent. spinning in one lot, and in all the percentage was about this. The seventh brood was still worse, about 35 per cent. of cocoons being got in one lot, and 50 per cent. in another. The weather was now warming up, dry west winds blowing. The next brood gave about 75 per cent. of cocoons, but the produce from it in the first stage was annihilated by the dry hot west winds presumably, acting upon the eggs produced from disease. It must also be remembered that the whole broods were the descendants of seven couples of moths originally. In the ninth brood from fresh seed, we got 80 per cent. of cocoons and 75 per cent.; this occurring

during July; the tenth brood gave eighty per cent., the next in September gave over 75 per cent., and the following one in November-December only 50 per cent.

In Pusa, the minimum temperature during December oscillates in the forties and so far as can be seen, this is the most serious factor. If worms are coming on to spin during times when the temperature falls below 50° F., then it is likely that many worms will die. On the other hand, temperatures above 105° F. are also injurious, but more to the quality than to the output of cocoons. The *ideal* conditions seem to lie in temperatures between 60 and 90, possible conditions between 50 and 100, and difficult conditions, necessitating great care, when the temperature goes for any long period over 100, or under 50. The last is especially serious in the case of worms spinning or moths emerging; worms require a temperature of over 60° F., preferably over 70° F., for three days, in which to spin; moths require the same in order to couple. At no other stage is cold serious; with a minimum temperature of under 50° F., the pupæ remain healthy in the cocoons, the eggs remain healthy and do not hatch, and the young worms remain healthy, feeding little; but if cold overtakes worms spinning, or moths coupling and egg-laying, the temperature must be kept up to 70° F. at least, and if possible up to 75° F. for three days.

We give here the mean monthly temperatures at Pusa, recorded by the Imperial Agricultural Chemist during the whole time we have been rearing eri silk, so as to afford data for comparing any district with Pusa, for which records of broods are given above. The humidity is taken at 8 A.M.

Months.		Mean Temperatures.		
		Maximum.	Minimum.	Humidity.
May,	1906	98·6	76·2	66%
June,	,,	96·5	78·4	78·9%
July,	,,	90·9	79·9	88%
August,	,,	87·0	78·5	88%
September,	,,	91·4	79·4	83%

Months.		Mean Temperatures. Maximum.	Minimum.	Humidity.
October,	1906	88·7	72·3	83%
November,	,,	83·5	59·9	81%
December,	,,	....	51·0	88%
January,	1907	....	51·4	89%
February,	,,	....	53·4	88%
March,	,,	....	57·1	74%
April,	,,	92·3	66·4	65%
May,	,,	98·0	73·5	64%
June,	,,	93·2	78·0	82%
July,	,,	87·9	78·7	92%
August,	,,	89·7	79·0	88%
September,	,,	90·6	77·2	89%
October,	,,	90·2	70·3	85%
November,	,,	84·7	58·3	83%
December,	,,	77·2	48·85	81%
January	1908	66·6	45·9	83%
February,	,,	77·3	51·9	82%
March,	,,	90·4	58·6	57%
April,	,,	103·9	72·3	52%
May,	,,	100·8	75·5	69%
June,	,,	98·7	79·7	78%
July,	,,	93·0	79·3	84%
August,	,,	93·8	78·3	84%
September,	,,	93·2	77·05	85%
October,	,,	93·08	66·07	71%
November,	,,	86·2	53·8	72%
December,	,,	78·6	45·1	82%
January,	1909	78·6	48·1	77%
February,	,,	82·5	47·9	67%
March,	,,	97·0	59·7	33%
April,	,,	94·3	68·6	67%
May,	,,	102·6	75·4	64%
June,	,,	91·5	77·6	86%
July,	,,	90·8	79·2	86%
August,	,,	88·1	77·7	86%
September,	,,	90·7	78·2	85%
October,	,,	89·0	69·3	83%
November,	,,	84·6	58·8	84%
December,	,,	75·9	50·0	91%

In the following list of localities the months are given in which the mean maximum is over 100° F., and we take those months to be unsuited to rearing, as also the months when the minimum is below 50° F., as then the worms will develop slowly, will not easily spin cocoons and the moths will not couple. In the latter case either the young worms or the pupæ in the cocoons must be expected to rest, or if there are worms spinning or moths emerging, the house must be warmed and kept at a temperature of 70° F., if possible. These months are therefore not well suited to extensive rearing.

The temperature figures are taken from Vol. XVII of the Indian Meteorological Memoirs and are stated to be usually averages of 25 years, in no case less than ten years.

Chittagong	
Silchar	
Barisal	
Narayanganj	
Mymensingh	
Saugor Island	
Calcutta	
Jessore	
Berhampore	.. April 100°.
Bogra	
Sibsagar	.. January 49·5.
Dhubri	
Burdwan	.. April 100·6.
Patna	.. April 100·6, May 100·2.
Gaya	.. April 103·4, May 104·9, (June 99·6).
Benares	.. April 103·1, May 105·5, June 100·1, December 48·2, January 48·2.
Jalpaiguri	....
Dinajpur	.. January 49·4.
Purnea	.. January 48·3, December 49·7.
Darbhanga	.. (Pusa is in this District, but records lower minima and higher maxima).
Gorakhpur	.. April 100·4, May 101·0, January 49·2.
Bahraich	.. May 103·0, (April 99·6), December 48·0, January 47·1.
Bareilly	.. (April 99·3), May 103·2, (June 99·7), December 46·0, January 46·1, February 49·7.
Roorkee	.. (April 98·2), May 102·8, June 100·4, November 49·8, December 43·5, January 44·4, February 47·7.
Umballa	.. May 105·2, June 101·4, December 43·5, January 43·3, February 47·8.
Ludhiana	.. May 104·4, June 104·8, December 44·0, January 44·3, February 47·5.
Sialkot	.. May 103·1, June 105·5, November 49·9, December 42·5, January 42·8, February 46·1.
Rawalpindi	.. June 102·8, November 43·3, December 37·1, January 37·9, February 41·4.
Dehra Dun	.. December 45·6, January 44·8, February 47·0.
Allahabad	.. April 103·8, May 107, June 101·7, December 47·8, January 47·9.
Lucknow	.. April 102·4, May 105·0, June 100·5, December 46·2, January 46·7.
Cawnpore	.. April 102·2, May 106·2, June 101·1, December 47·6, January 47·1.
Mainpuri	.. April 102·5, May 107·5, June 101·2, December 47·3, January 46·1.
Agra	.. April 102·6, May 107·2, June 104·3, December 48·8, January 48·6.
Meerut	.. May 103, June 100·6, December 44·7, January 45·0, February 48·4.
Delhi	.. May 104·7, June 103·2, December 48·9, January 47·9.
Lahore	.. (April 108·2), May 105·7, June 107·4, July 100·6, November 46·8, December 40·3, January 40·7, February 44·1.
Peshawar	.. June 105·9, July 102·9, (August 99·2), November 45·1, December 39·0, January 39·6, February 42·6.

Dehra Ismail Khan ..	May 104·2, June 108·0, July 103·4, August 101·1, September 100·5, November 47·0, December 40·1, January 40·4, February 44·9.
Montgomery ..	April 100·1, May 108·3, June 110·0, July 104·7, August 102·0, September 101·7, December 43·0, January 42·2, February 46·4.
Multan ..	May 106·6, June 107·8, July 103·8, August 100·7, September 100·3, December 44·4, January 43·3, February 47·5.
Sirsa ..	April 101·1, May 107·2, June 106·7, July 100·5, November 49·5, December 42·7, January 43·1, February 46·8.
Bikaneer ..	April 101·3, May 107·1, June 106·5, July 100·4. January 49·4.
Pachpadra ..	April 106·3, May 107·8, June 105·7, December 46·3, January, 45·1, February 48·9.
Karachi	....
Hyderabad (Sind) ..	April 102·7, May 106·9, June 104·2.
Jacobabad ..	April 103·1, May 111·6, June 112·7, July 107·8, August 103·8, September 103·5, December 44·0, January 43·3, February 48·5.
Quetta ..	September 49·5, October 38·3, November 32·1, December 29·7, January 29·3, February 31·7. March 40·0, April 46·3.
Chaman ..	June 100·2, July 101·5.
Trivandrum ..	....
Cochin ..	....
Calicut ..	....
Mangalore ..	....
Mercara ..	....
Karwar ..	....
Goa ..	....
Marmugoa ..	....
Ratnagiri ..	....
Bombay ..	....
Surat ..	April 100·1.
Bhavnagar ..	April 100·8, May 102·9.
Veraval ..	....
Rajkot ..	April 102·8, May 105·4, (June 99·8).
Bhuj ..	April 101·0, May 101·3.
Ahmedabad ..	April 105·4, May 107·1, (June 99·4).
Deesa ..	April 104·2, May 106·7, June 101·9.
Tinnevelly ..	April 100·4.
Madura ..	April 100·1.
Trichinopoly ..	April 101·1, May 101·8, (June 99·0).
Coimbatore ..	....
Salem ..	April 100·7.
Mysore ..	....
Bangalore ..	....
Hassan ..	....
Chitaldroog ..	..
Cuddapah ..	March 101·7, April 105·2, May 106·3, June 100·3.
Kurnool ..	March 100·9, April 103·6, May 104·8.
Bellary ..	March 100·3, April 103·4, May 102·4.
Raichur ..	April 102·1, May 103·4.
Hyderabad (Deccan) ..	April 102·0, May 103·8.
Gulbarga ..	(March 99·2), April 103·2, May 104·8.
Belgaum ..	....
Bijapur ..	(April 99·8), May 100·3.
Sholapur ..	March 100·4, April 104·8, May 104·8.

Poona	.. April 101·6, (May 99·2).
Ahmednagar	.. (April 98·9, May 99·4).
Malegaon	.. April 103·2, May 104·0.
Buldana	.. April 100, May 101·1.
Chikalda	.. ....
Akola	.. (March 99·2), April 106·0, May 107·7.
Amraoti	.. (March 98·1), April 105·0, May 107·7.
Khandwa	.. April 104·8, May 106·5.
Nagpur	.. April 105·5, May 109·3, (June 98·3).
Indore	.. April 100·6, May 102·8, December 49·3, January 49·8.
Neemuch	.. April 100·9, May 104, December 49·5, January 48·7.
Ajmere	.. (April 99·3), May 103·8, June 100·5, December 45·6, January 45·5, February 49·4.
Sambhar	.. April 100·4, May 105·1, June 102·3, December 46·3, January 45·4, February 49·7.
Jaipur	.. April 101·7, May 106·6, June 102·5, December 49·1, January 48.
Saugor	.. April 101·5, May 105·1.
Sutna	.. April 101·7, May 105·5, December 47·1, January 47·6.
Nowgong	.. April 103·4, May 107·4, June 101·6, December 46·4, January 47.
Jhansi	.. April 104·2, May 108·2, June 102·8.
Hoshangabad	.. April 104·8, May 107·6.
Pachmarhi	.. December 45·7, January 47·5.
Jubbulpore	.. April 102, May 105·6, December 46, January 48.
Seoni	.. April 101·1, May 103·9, December 49·8.
Chanda	.. April 106·5, May 109·5, (June 98·5).
Raipur	.. April 104·3, May 107·4.
Sambalpur	.. April 104·3, May 106·9.
Chaibassa	.. April 103·6, May 105·1.
Ranchi	.. (May 99·6).
Hazaribagh	.. (May 99·2).
Balasore	.. ....
Cuttack	.. April 102, May 101·6.
Gopalpur	.. ....
Waltair	.. ....
Cocanada	.. May 100·7.
Masulipatam	.. May 100·1.
Nellore	.. April 100·9, May 106, June 101·8.
Madras	.. ....
Cuddalore	.. ....
Negapatam	.. ....

Disease.

Examination of the records of broods above will show that there were periods when large numbers of worms died. These are attributed to want of leaf or bad leaf or to bad management, but are in the end directly due to disease, brought on by bad management. It is said that eri silkworms suffer from the diseases of mulberry silkworms, *viz.*, pebrine, flacherie, grasserie, muscardine.

We note below concerning these, but *flacherie as such* does not exist in eri nor could it; flacherie in mulberry silkworms is stated to be connected with *Streptococcus* and *Vibrio* from the mulberry leaf or at any rate with bacilli living in mulberry leaf in the insect's stomach. A disease of a similar nature connected perhaps with the castor leaf occurs in eri; we may call this "flacherie" but this must inevitably give rise to confusion. We prefer to call it "bacillar disease," as conveying at least a definite idea apart from flacherie and associating the name with one symptom. This disease is being investigated at present by the Imperial Agricultural Bacteriologist, Mr. C. M. Hutchinson. We do not propose to deal with it here, but to discuss it in a later publication.

PEBRINE.

In one brood, worms died with symptoms pointing to pebrine. The presence of pebrine was suspected by Dr. Butler and was confirmed by the examination of worms and moths by Mr. MacNamara, Assistant Director of Sericulture, Kashmir. The disease has not assumed any real importance and we have not as yet found any necessity for microscopic examination of moths.

MUSCARDINE.

In one lot of worms from seed imported from another locality, the worms died from a disease showing the symptoms of Muscardine; this is the only occasion on which this disease has appeared and it did not affect other broods going on at the same time. Disinfection of all trays and baskets is the important thing in this case.

THE FLY PARASITE.

The most important enemy to this silkworm is the parasite, a fly of the family *Tachinidæ* whose maggot lives in the worm and destroys it. This insect is at present limited in its distribution and it would be extremely unwise to introduce it to new localities. Cocoons should never be obtained, but eggs; the eggs cannot carry parasites, only the worms or cocoons can do so, and we would most

strongly urge that, if seed is required to commence or to invigorate, only healthy eggs should be obtained and never cocoons. In any case it is unwise to import cocoons from Assam at all, as they are obtainable from other parts of India where the parasite does not occur.

Other Enemies.

Rats are determined destroyers of the eri silk insect in all stages, and if the worms are being reared in an infested building, precautions are required. A plentiful use of traps and rat-poisons is usually sufficient; the cocoons before emergence of the moth are specially attacked and they may require to be kept in closed baskets hung from a string.

Ants are fond of the young worms and the legs of the *machans* may require to be tarred or smeared with Crude Oil Emulsion, which effectively keeps off ants.

In one case it was found that bats came in at night and cut the cocoons, feeding on the pupa; this is only to be avoided by preventing access of bats at all.

The Importance of Disease.

Until eri silk has been cultivated on a large scale for a longer period, the importance of disease cannot be estimated. We have had outbreaks of all forms of disease in one brood or another of several going on together, but not in all at one time. Rearers in Tirhoot have lost worms from disease, but in almost all cases bad feeding, bringing leaf long distances, or some other irregularity may have been the predisposing cause; there is little real information about the diseases of eri silkworms and the names of the disease of mulberry silkworms, most like that from which the eri worms are suffering, are used rather indiscriminately to denote what may be quite different diseases in eri silk. So far as our experience goes up to now, with proper feeding, clean trays, proper spinning methods, disease is not very important unless the climatic conditions are really unsuitable; if very dry hot weather sets in with a dry wind full of dust, disease may overcome the worms and the

mortality may be very large. So also with worms in the last stage and at spinning if the temperature is below 60° F. indoors. On the other hand, we have not had long enough experience to tell really how far disease is important and the question will have to be kept in view. *We would recommend all rearers to have their names and addresses registered for exchange of seed ;* a register is maintained at Pusa of all rearers known to us and so far as possible we arrange for exchange of seed between rearers in different localities.

In this connection the following circular has been issued :—

Eri Seed Supply.

An essential feature of good rearing is the exchange of seed and renewal of the stock from some distant place. Arrangements have been made for seed supply from several places ; as the demand for seed is fluctuating and not easy to arrange, it is essential to get the co-operation of as many rearers as possible. We propose to arrange as far as possible for the following :—

(1) Seed supply at fixed prices from certain centres.

(2) Register names of those who will want seed and the times they will want it.

(3) Register those willing to supply seed, either at a fixed rate or by exchange with a rearer in another place.

The rate proposed for the sale of seed is as follows :—

200	0	8
500	0	12
1,000	1	0
5,000	1	8
10,000	2	0
16,000 (1 oz.)	2	8
32,000 (2 oz.)	3	8

Those who are prepared to enter into this arrangement should (1) agree to the above scale ; (2) inform me in advance when they expect to have surplus seed for sale ; (3) inform me in advance when they expect to have surplus seed that they wish to exchange ; (4) inform me in advance when they will want to purchase seed ; (5) inform me at once if they wish to have a fresh supply of seed

every year at one season and expect to have surplus seed every year at another season.

The benefit of these arrangements to rearers will be great; in the first place, all rearers in some districts will want seed in July and will have surplus seed in March; others will want seed in March and have surplus seed in July-August; large rearers will have large surpluses of eggs for sale at different seasons and in some localities seed can be obtained and is required at all times; another benefit will lie in exchanging seed from widely separated localities, *e.g.*, Gujarat and Behar, South India and North India, etc.

Pusa can no longer supply all the seed, but if rearers desirous of coming into this arrangement will register their names, requirements and outturn of surplus seed, we will endeavour to put those requiring seed into touch with those supplying it.

In this connection, we would draw very special attention to the fact that many rearers, beginning from a good healthy stock, have in a few broods got disease, while other rearers with the same stock, have not had disease. We believe this to be wholly due to bad and good feeding respectively; and as a general rule with those who have started rearing eri silk during the last year, those who have fed often, giving good leaf in good condition at frequent intervals, have produced fine cocoons and a healthy stock, while those who have fed badly or have been careless have very largely had their stocks wiped out by disease.

In the Pusa rearings given above, the serious shortages of leaf have always led to large outbreaks of disease, and comparing these broods with broods of other places who got their seed from Pusa, there has been a marked superiority in the cocoons from rearers outside and they have also produced a far finer stock.

In Assam, where eri silk-rearing is general, there is much disease, but the industry is a subsidiary cottage one and disease does not matter very much. Also it must be remembered that the loss of the worms is far less important than with other kinds of silkworm, as in eri all the moths can be allowed to lay eggs without

loss of cocoons, whereas every moth allowed to emerge in tasar or mulberry silk means a cocoon unreelable.

Results obtained by rearers who have obtained seed from Pusa have varied immensely; some have been quite successful, some have failed; our own experience has been that eri silkworms are far more difficult to rear than mulberry silkworms, doing the two side by side in the same rearing house, so that there is either an inherent difference in the species or something vitally wrong in the food, the conditions or some treatment or else the disease is the important factor. The last is the controlling factor at present, and until it has been worked out, we must anticipate losses from disease and renew our seed periodically, ceasing cultivation altogether when the want of leaf, bad leaf or adverse climatic conditions compel us to.

It has been seen that climatic conditions have much to do with whether disease will prevail at all. The same stock which suffers badly from disease in April and May gives good results in July-August. On several occasions a number of worms has been picked out of a lot, diseased and dying in April-May and kept in a humid condition. They have been successfully reared, although some of them have been fed with leaves soaked in the juice of the body of diseased and dead worms. If the climatic conditions are favourable, the worms will normally resist the disease provided proper conditions of management and food-supply are kept up.

TREATMENT OF COCOONS.

Reeling, Cleaning, Boiling off, Carding, Spinning, Weaving, Bleaching, Dyeing.

Reeling.

It has been assumed in the past that eri, being an open cocoon, could not be reeled. There are two reasons given for this : one that the thread is not continuous, ending constantly at the open mouth ; the other that the cocoon being open, will, when placed in hot water for reeling, fill with water and sink, rendering reeling, as ordinarily practised, difficult. The latter objection can be overcome by putting the cocoons on wire gauze in the boiling water so as to keep them always at the right level; the former is actually not valid, as the thread does not end at the mouth, which is closed with loops. The cocoon is, however, different in fundamental structure from other cocoons and we have seen experienced reelers fail to reel it.

With mulberry and tasar cocoons, the thread can be reeled off in a length of 500 to 700 yards, provided the end can be found ; a large part of the cocoon is practically homogeneous, formed of one thread going round and round, and more or less continuous. In eri silk, the cocoon is composed of (1) the cradle, (2) a number of detachable layers, from three to seven, (3) an inner layer where the thread weakens off and is much covered and cemented with gum forming a shiny smooth layer. Instead of being a perfect oval with both ends alike and hard, one end is hard and even, the other is open and loose ; there are also "patches," where a piece woven closely and not in circles round, is detached as a tangle. In actual reeling, the thread comes off for a time, then picks up a number of others or works under a patch and brings it off as a tangle. Actual threads as long as 20 feet can be readily got

off a layer, but sooner or later several threads foul, or a "patch" comes off. We do not believe that reeling, as done usually, is possible for these reasons : the worm does not spin its cocoon as the mulberry worm does ; it makes the cradle ; then it makes layers (usually seven or eight) with rests between ; it spins loops at the mouth, but circles or ovals at the closed end ; it strengthens spots of the cocoon with discontinuous patches. It is, of course, impossible to see what goes on in the cocoon after a certain point, but from an examination of very many cocoons treated in different ways, we do not believe that, in the ordinary way, the cocoons can be reeled. Whether a system of reeling can be devised by experts in reeling remains to be seen, but we believe that reeling, as now practised, cannot be applied to this cocoon, whether to cocoons from which the moths have emerged or to cocoons from which the moth has not emerged and in which the chrysalis has been stifled. Nor is it likely that reeling, if possible by experts, could ever be simplified so that it could be done cheaply and with ordinary labour.

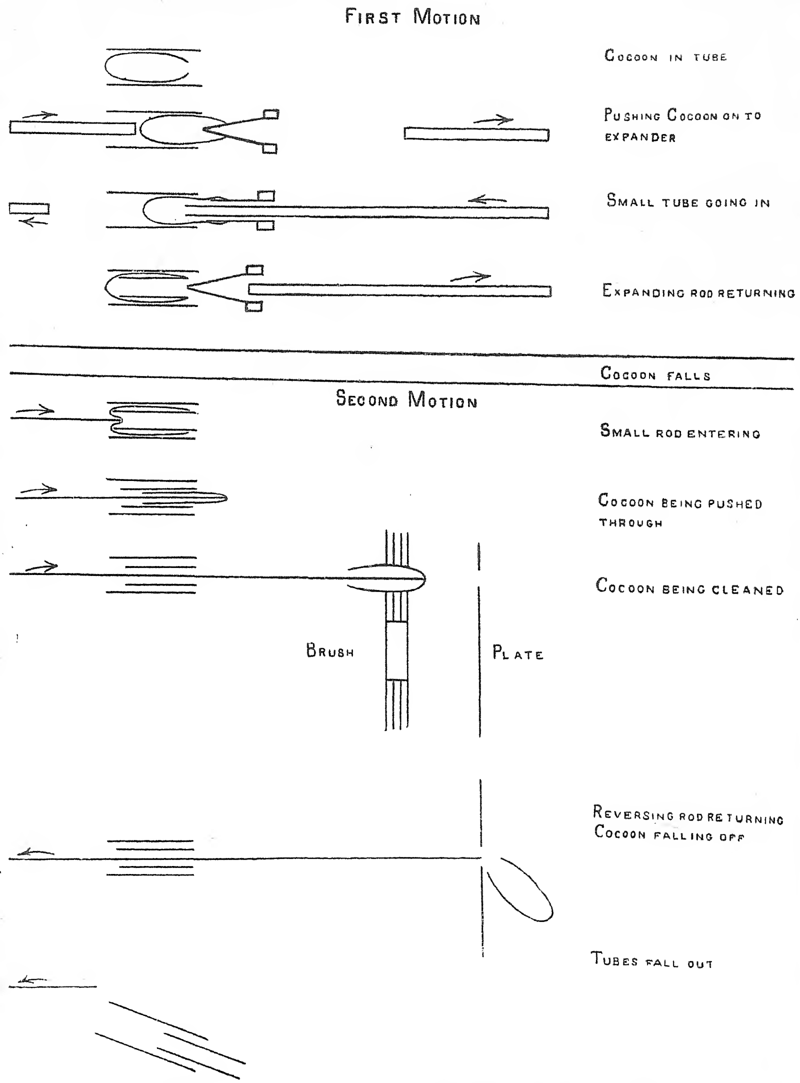
Another factor in reeling is this : in mulberry silk, the gum of the silk is softened in hot water and as the fibre from each cocoon joins the others at the eye, they consolidate into one thread, the gum on the fibre uniting them as it cools and dries. In eri silk, the fibres, after passing through the eye, separate again, the gum not uniting them as in mulberry silk. The physical properties of eri silk are very different from mulberry silk [as also from tasar silk] and the chemical composition of the gum is evidently different, as will be seen when cocoons are boiled.

Cleaning Cocoons.

When the moth emerges from the cocoon, it leaves behind it the empty pupal skin as well as the old dried caterpillar skin. If the cocoons are carded, these remains get broken up, mixed with the silk and have to be removed by special methods. If the cocoons are used for spinning, the spinner must use care to avoid spinning in fragments, must waste the inner layer of the cocoon, and, in

boiling the cocoons, much dirt comes out in the water and stains the cocoons. It is in every way desirable to clean the cocoons and a process for doing so has been discovered.

If an unboiled cocoon is taken in the fingers and a tapering piece of wood, such as the handle of a long penholder is pressed against the closed end, the closed end may be pushed through the open end and the cocoon turned inside out. In so doing all the dirt is pushed out and a perfectly clean cocoon obtained. This is the principle employed in this process; the principle and machines for doing it have been patented by the inventor, Mr. R. W. Coryton. If the work is done by hand as described, it is excessively tedious and slow. The machines are the only successful method of doing it. There are two machines, a simple hand one and a more complex hand or power one. The working of the latter machine is this: each cocoon is placed in a brass tube, after its mouth has been slightly opened. The tubes are placed on an inclined shoot on the machine with the open end of the cocoon to the right. They slide down one by one as the machine works; each cartridge comes opposite a hole at the left side of the shoot, through which comes a rod, which pushes the cocoon to the right on to an expander which enters the opening; the expander is then expanded by the pressure of a small brass tube which is forced into it from the right and which passes right into the cocoon; the rod pushing in the small tube pushes it off the expander back into the first tube; we now have the cocoon back with a small tube inside it. The two tubes and cocoon then drop and come opposite another, opening in the shoot, on the left, through which comes a small steel rod, which pushes the closed end of the cocoon into the small tube and turns the cocoon inside out, pushing it right through the small tube, beyond it, through revolving brushes and through a plate, where, as the rod returns, the cocoon falls off into a shoot and comes out of the machine. The rod returns to the left, clear of the cartridges which fall through into another shoot. Meanwhile another cocoon has come down above and been provided with its inner tube. At each cycle one cocoon gets its tube, another gets pushed out and so



WORKING DIAGRAM OF CORYTON'S COCOON REVERSING MACHINE (LARGE MODEL).

on. By simply feeding large tubes containing cocoons down one shoot, small empty tubes down another and turning a handle, cleaned cocoons are turned out at the rate of 30 to 60 per minute.

The same inventor has devised a simple apparatus for effecting the same thing in a simpler manner suited to the small grower and requiring no elaborate apparatus. The machine consists of a fixed expander, through which is pushed a brass tube fitted inside with a spring; opposite is a fixed steel rod which strikes against the closed end of the cocoon and reverses it while entering the tube. The spring pushes out the cocoon as the tube is drawn back.

To prevent the cocoon striking on the rod, a swinging fork pushes it off as the tube is drawn back, the fork being weighted below. For this machine, dry, well-opened cocoons are essential. The instructions given below sufficiently explain the machine.

INSTRUCTIONS FOR ERECTING AND WORKING

CORYTON'S PATENT ERI SILK COCOON REVERSER. (FIG. 10.)

MODEL II.

Object of the Machine.

When emerging from the cocoon through the aperture left in it by the caterpillar when spinning, the Eri Silk Moth leaves behind it inside the cocoon the skin of the pupa, also often some excrement and other foreign matter.

If this extraneous matter is not removed prior to boiling the cocoons to degum them, not only is the silk discoloured but the pupal skin, etc., becomes entangled with the silk and causes a considerable quantity of waste when cleaning.

The object of this machine is primarily to reverse the cocoon before it is boiled, and so clean it. In this condition, all foreign matter can be easily freed from the parchment-like skin that forms the inner lining of the cocoon. Secondarily, to afford buyers of cocoons a certainty that they are buying silk and silk only. When a demand for these cocoons arises, growers may try to increase their profits by killing the moths before they emerge and thus increase the weight of the cocoon.

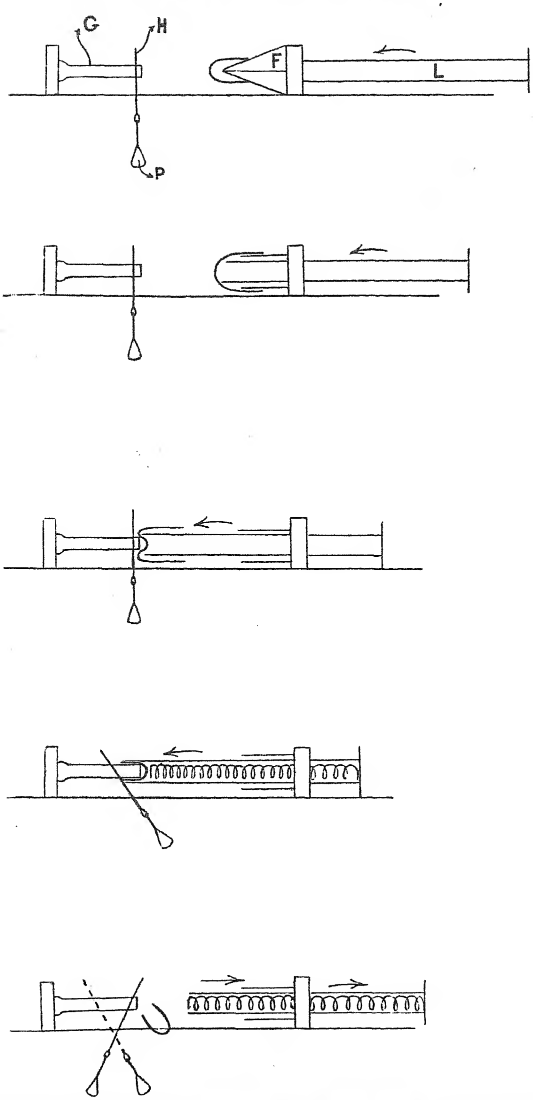
Buyers would do well by themselves to hire these machines out to the native growers and insist on purchasing reversed cocoons only.

To erect the machine.

Take the machine out of the box in which it and a pair of stretchers are packed.

Place the wooden stand " A " so that the slot " B " in the top cross bar " C " is closer to the leg that is further away from where the operator is to sit.

SCALE — 12 INCHES



WORKING DIAGRAM TO SHOW ACTION OF CORYTON'S COCOON REVERSER (HAND MODEL).

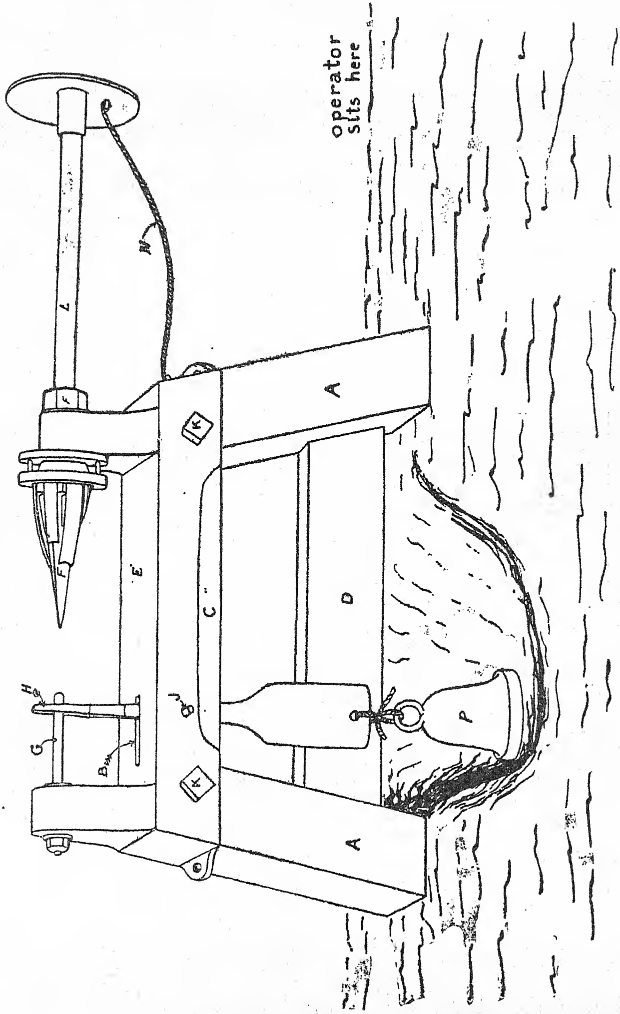


FIG. 10. CORYTON COCOON REVERSING MACHINE.

Bury the legs of the stand so that the lower cross bar "D" is at ground level. Ram earth round the legs to keep the machine firm.

Place the casting "E" on the stand, seeing that the slot in the casting and cross bar of the frame coincide and secure by the bolts K. K. to the stand.

If correctly fixed, the expander "F" will be towards the operator (pointing away from him) and the reversing point "G" further away and pointing towards him.

Pass the forked brass pendulum "H" through the slot, the fork passing on either side of the point "G." Pivot on the pin "J" passed right through the casting and top cross bar.

Hang on the pendulum weight "P." The pendulum should swing freely. Push the brass tube "L" about 2″ into the Expander "F" and adjust the cord "N" to prevent the tube "L" being drawn too far back after each operation.

A *small* amount of oil may be applied to the tube with advantage.

The machine is now ready for use. Two points must be especially noticed before it is attempted to reverse the cocoons.

(*a*) The cocoon must be dry.

(*b*) The cocoons must be pierced and the moth emerged from them.

To operate the machine.

Take the cocoon between the first finger and thumb of both hands and open the passage made by the moth when emerging from the cocoon.

Insert half way down the cocoon the stretchers (sent with every machine)—and open the mouth of the cocoon as much as the stretchers will allow.

Place the cocoon on the points of the expander taking care that the expander is not inserted more than $\frac{2}{3}$rds of the way down the cocoon.

Push home the brass tube by applying pressure on the palm-plate and the cocoon will be pushed off the expanding points and on meeting the reversing pin "G" will disappear up the tube "L." Draw the tube back again to the full extent of the cord and the cocoon, now reversed, will be ejected off the reversing point (Fig. 11).

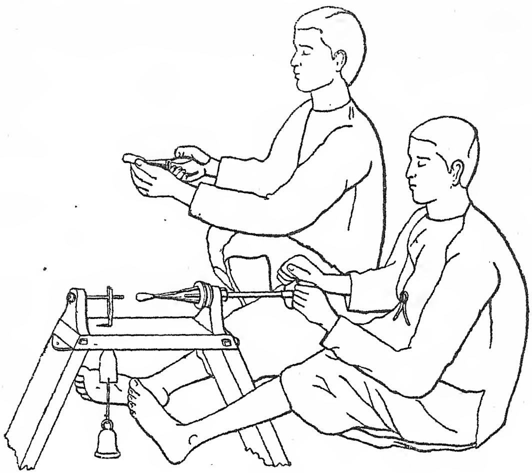


FIG. 11.

Occasionally an extra large cocoon sticks in the tube. A small bit of bamboo the thickness of a lead pencil if inserted in the back of the tube stimulates into action the ejecting spring which is inside the brass tube.

BOILING OFF.

The thread of the cocoon consists of a core of fibroin, and a covering of sericin or gum; the latter causes the threads to adhere

and to form the close texture of the inner layer of the cocoon. Before spinning the threads, the gum must be dissolved sufficiently to free the threads. This is done by treatment with a weak alkali. The ordinary practice in Assam is to take sufficient water to cover the cocoons, to dissolve in it a weight of castor ash equal to the weight of silk and then to boil till the cocoons are soft throughout. To prevent entanglement of the cocoons they are placed in a cloth, not directly into the liquid. Castor ash was analysed :—

"ASH FOR THE SAPONIFICATION AND CLEANING OF SILK.

Water soluble portion contains practically nothing but a mixture of the Sulphates and Chlorides of Magnesium and Potassium together with 28·3% of Potassium Carbonate. In order to replace its use as a saponifying agent by that of a pure salt, use equivalent proportion of Potassium Carbonate. Since, however, Potassium Carbonate $K_3 CO_2$ is very deliquescent, it will be necessary to first analyse the ordinary commercial Potassium Carbonate before using, then use in the proportion indicated by the above analysis."

A number of experiments were made to determine if ordinary soda (Sodium Carbonate) could not be used, as the crude ash is dirty and impure. The following are results of trials :—

I.	Silk 100 grains. Soda 12½ grains. Water 200 c.c. Boiled for 25 minutes.	Unsatisfactory.
II.	Silk 30 grains. Soda 7½ grains. Water 100 c.c. Boiled for 15 minutes.	Quite satisfactory.
III.	Silk 30 grains. Soda 15 grains. Water 100 c.c. Boiled for 10 minutes.	Not good.
IV.	Silk 30 grains. Soda 30 grains. Water 100 c.c. Boiled for 10 minutes.	Quite satisfactory.
V.	Silk 30 grains. Soda 45 grains. Water 100 c.c. Boiled for 5 minutes.	Not satisfactory.

VI. Half a seer and not more pierced cocoons can be conveniently boiled in a kerosene tin. Half a seer of castor ashes necessary with 2 gallons (*i.e.*, half a tin) of water for this weight of silk. Boiled for from 45 minutes to 1 hour.

$\frac{1}{4}$ pound soda.
2 gallons water.

In this cocoons soaked first and then tied in a piece of cloth (as usual with ashes) and then the cocoons boiled. Some loose cocoons were also boiled along with the bundle to see when the gum of these loose cocoons would be completely dissolved; it was dissolved after full half an hour's boil (compare expt. II). The bundle was boiled for 45 minutes so that the action of the soda would be perfect even on the innermost cocoons in the bundle. This gave a perfectly satisfactory result. This experiment was identically the same as II, but the results were so different on account of the quantity of the cocoon and water.

$\frac{1}{2}$ seer of cocoons.
$\frac{1}{4}$ seer of soda.
2 gallons of water.

In the following experiments, other reagents were used for boiling off, as it was found that the cocoons were whiter if boiled with soap or caustic alkali.

1. *Caustic Soda*, 5%.
   Cocoons 875 grains.
   Caustic soda 44 grains.
   Water $1\frac{1}{4}$ pint.

The soda was dissolved in water and placed on the fire: it boiled in 10 minutes, the cocoons were put in and in 15 minutes the gum was dissolved.

2. *Bar Soap*, $12\frac{1}{2}$%.
   Cocoons 875 grains.
   Soap 110 ,,
   Water $1\frac{1}{2}$ pints.

The soap was cut and boiled until dissolved. The cocoons were put in and boiled for half an hour; the gum was not dissolved and the cocoons were left in for 24 hours, when the gum was dissolved.

3. *Washing Soda*, 25%.
   Cocoons 875 grains.
   Soda 219 ,,
   Water $1\frac{1}{4}$ pint.

The soda was dissolved and boiled; the cocoons were put in and boiled for 15 minutes when they were ready.

4. *Bar Soap*, 25%, *not boiled.*
   Cocoons 875 grains.
   Bar soap 219 ,,
   Water $1\frac{1}{4}$ pints.

The soap was cut up, boiled in the water and dissolved and the solution removed from the fire. The cocoons were put in; some were ready in 6 hours, but after 20 hours most were not ready and required boiling for 15 minutes.

5. *Caustic Soda, 5%, without boiling.*
Cocoons 875 grains.
Caustic soda 44 grains.
Water $1\frac{1}{2}$ pints.

The cocoons were put in the boiling solution after removal from the fire and were ready in 12 hours.

6. *Soda Crystals, 25%, without boiling.*
Cocoons 875 grains.
Soda 219 ,,
Water $1\frac{1}{2}$ pints.

The cocoons were put in the boiling solution, removed from the fire, and allowed to stay there 20 hours. They were not ready and required boiling for 20 minutes.

The best method of boiling we believe to be as follows: Soak the cocoons in water for 18 hours, changing the water several times; then boil in Crystal soda, 25% of the weight of the cocoons (2 chittacks to half a seer of cocoons in a kerosene tin) for 45 minutes or 12% of Mono-hydrated soda (1 chittack to $\frac{1}{2}$ seer of cocoons in a kerosene tin); then remove the cocoons and wash; then put into and move about, or boil for a few minutes in a hot soap solution (10% of the weight of the silk). Then wash in running water or several changes. This leaves the cocoons white and clean, in a fit condition to dye or to spin.

In practice we omit the soap as, for ordinary work, we do not require the cocoons to be very white. If it is desired to make them very white, they should be treated with soap and after washing put for a few moments into dilute Sulphuric acid ($\frac{1}{2}$ per cent. in water). This makes the cocoons white and gives the stiff "Scroopy" feeling; if this is not required, wash out the acid and put into dilute soap or soda solution, and then wash well; they will be very white but not "Scroopy." The above processes of washing apply to uncleaned cocoons; if one is working with clean (reversed) cocoons,

one can omit the preliminary soakings and washings, as there is no dirt in the cocoons.

This process of treating cocoons is radically different from that used for mulberry silk and the methods used for mulberry silk do not apply to eri. The greatest difference between mulberry and eri silks, as silks, lies in their composition; this has not, so far as we are aware, been chemically investigated; mulberry silk is far more easily divested of its gum, is far less resistant to the action of alkalies and can be treated by a process of maceration, with perhaps a short boiling in soap after. Eri silk cannot be so treated; we have not been able to treat cocoons by any process of maceration with subsequent boiling in soap; boiling with soap does free eri silk from gum, but not as well or as quickly as soda does; in actual practice, eri silk can be boiled with 12% of its weight of monohydrated Sodium carbonate without suffering in strength; such drastic treatment would not be adopted for mulberry silk, nor is it required. In this respect eri silk is like "wild silks" such as tasar, that is, all the silks in the trade not derived from *Bombyx*.

CARDING.

Boiled dry cocoons are very readily carded by hand for hand-spinning if this is required and this effects a separation of the dirt contained in the cocoon from the fibre. The simplest method is simply to take each cocoon in the fingers and with each hand to gently loosen the cocoon till it all comes away as a loose fluffy mass, leaving the very thin inner shell holding the empty chrysalis case and caterpillar skin. There is a small amount of waste, but this can be recovered by fresh boiling. If carding were a necessary preliminary to spinning, it would be worth while devising a hand machine to do it; but, while carded silk can be spun, especially on the charka, it is not necessary or desirable. In the Punjab, wool is carded and those who do this can also card eri cocoons and then spin a fine even thread just as is done with wool. It may be found desirable to do this where wool-carding and spinning is familiar to the people and

if so, hand-carding is a very light occupation for children which they learn at once. We do not use carded cocoons as a rule.

SPINNING.

There are three methods of hand-spinning in use at present.

(1). The Taku or Spindle (Fig. 12) is a simple spindle with a weighted end; the spindle is attached to the drawn-out end of the wet cocoon and spun, the thread being drawn out evenly by the fingers till the spindle falls sufficiently when the thread formed is wound off and the spindle again spun to twist a fresh length. It is a slow process, well-known for making "Matka" thread of waste mulberry silk and is the least economical of the methods, though it produces good thread.

FIG. 12.

(2). The "Charka" (Fig. 13) or Spinning Wheel is familiar wherever cotton is spun. It consists of a wheel with a belt which

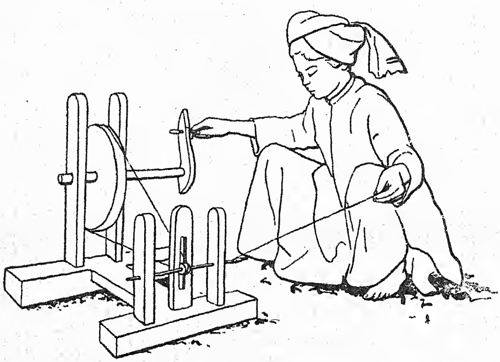
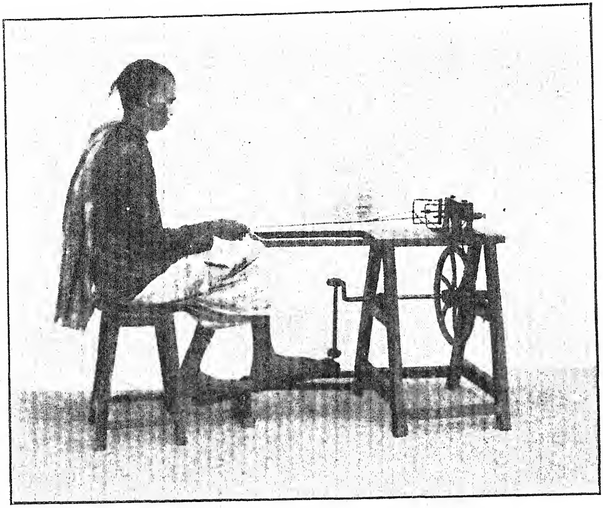
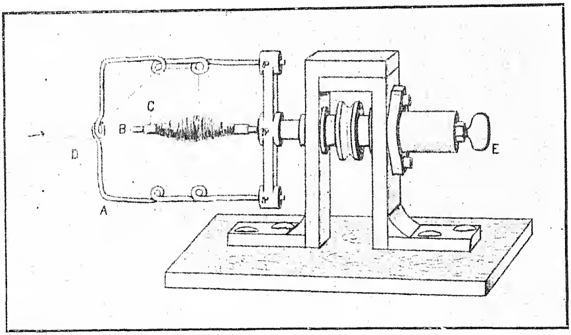


FIG. 13.

PLATE IX.





THE PUSA CONTINUOUS SPINNING MACHINE.

passes round a small pointed spindle set between uprights; the wheel is turned with one hand, causing the pointed spindle to revolve rapidly; if it has been joined to a pulled-out end of the cocoon and the cocoon is pulled away by the left hand, the thread is twisted and drawn out; when the cocoon is held out as far as possible, the thread is disengaged from the point and is wound off upon the base of the spindle, and a fresh length begun. Dry or carded cocoons are done very well upon this machine, which makes very fine thread. The sole disadvantage is that the process is not continuous, as the wheel must be stopped to wind the finished length on to the spindle: only one hand is available for the cocoon, the other being used to turn the wheel. This process is the familiar one in India and it is one of the advantages of the industry that the material can be so readily used in this way in India generally; the people have nothing to learn.

(3). *The Pusa Machine.* An improvement upon the above has been devised, based upon the old "flying needle" principle, so universal in power-spinning of all kinds. The principle of the machine is this: a thread passes to a point revolving round a revolving spindle and from it to the spindle; if the two revolve at the same rate, the thread is only twisted or only wound on the spindle according as they revolve in the same or opposite directions, but if they revolve at different rates, the thread is dragged from the revolving point and wound off upon the spindle; in so doing, the revolutions of the point give the thread twist, and if the fine end of the cocoon is fed in, it becomes thread, as it is drawn off and twisted.

If the two motions are adjusted, one can get in a given length a definite amount of twist; thus if one inch of thread is drawn in while the flying point makes six revolutions, the thread will have six twists in one inch. To secure that, there shall be a difference in the rates of motion of the spindle and the needle can be done in two ways; they may be driven by belts off pulleys of unequal size, or the spindle may be free to revolve and slightly "braked;" if the spindle is free to revolve, the thread drags it round and is not

wound off; but if the spindle is braked by friction, it turns more slowly than the needle and so pulls off the thread. The details of such a machine will vary, but the principle is the same; the Pusa Machine consists of a pulley, turned by a treadle and belted to the flying needle; the needle may actually be a hollow bent needle, or a wire with a loop at the end and other loops on the arms. It revolves round the spindle, which revolves more slowly and the thread is fed in at the base of the needle or through the loop at the end; the spinner has both hands free to draw out the cocoon into a proper length and feed it continuously to the thread.

The great advantage of the machine is that it brings the fibre off the cocoon in very long individual strands; it is really a process of very coarse reeling and the "staple" of the fibre is very long. Wet cocoons are used as they give the best results but carded or dry cocoons can also be used. The photograph illustrates the machine best; there are several available patterns, the best doing two threads at once, not a single one.

In spinning, there is a certain amount of waste but not a very great one. There is of course a very large amount of loss of weight prior to spinning; thus about 17 per cent. of the cocoon is old pupal and larval remains; another 8 per cent. boils off as gum; the average figures for dry empty cocoons are as follows:—

Dry cocoons 100.
Dry cleaned cocoons 78.
Boiled „ „ 70.
Thread 65.
One seer of raw cocoons gives 10 to 12 chittacks of thread.

Preparation of Thread.

The thread as prepared by the spinner undergoes no special preparation before it is used for the warp or put in the shuttle except the processes usually adopted by the local weavers with cotton. The warp threads are run off on to big spools, warped, the warp arranged, stretched, sized and brushed; the weft threads are run off on to small pirns for the shuttles and kept wet till wanted. In

case of extra thick thread being required for a coloured border, two or more threads are twisted together either in the usual way of bobbins on a charka or in whatever way is used locally. For eri fabrics as commonly produced there is no special preparation and in weaving it is treated just as cotton thread is.

Weaving. A Handspun Thread.

The threads produced from the charka, taku or continuous spinning machine are woven in the usual way on the ordinary hand-looms of this country. They are not adapted to power looms unless very well spun as they break. In the ordinary process of sizing, warping and weaving, the threads become very dirty, so dirty that the pure white cocoons become "écru" colour, the dirty colour of Assam eri silk. With careful sizing and weaving this may be avoided. We have used various looms and here express no opinion as to which pattern is the best. A loom that weaves cotton will weave spun eri silk and which loom will suit any locality best depends purely on local circumstances. As a rule, eri silk is woven into moderately coarse cloth, either for suits or for use as whole pieces uncut as wrappers, saris, dhotis, etc. These are either natural colour, or cream colour, the latter being obtained by bleaching with sulphur. Into these a coloured warp border may be woven, doubling the thread of the warp at the edge, or a coloured end border, using thicker coloured thread for the weft at each end.

It can be woven into twills, tartans, checks, stripes, etc., by the usual methods, but these can never be as light and thin as are produced from reeled mulberry silk and are not the beautiful fine fabrics produced from such silks. The fineness and gloss of mulberry silk cannot be got; by fine hand spinning and good weaving one can get a fine cloth, with little gloss, with great softness and extreme durability. With ordinary spinning and weaving, heavier cloth is produced suitable for wearing, for coloured table cloths and curtains, for those fabrics in which strength and durability are required but not the sheen or delicacy of the finest silks. Most silks deteriorate with use; eri silk improves, since the soft fibre loosens a little, fills

in the fabric between the threads and gains in lustre and softness. The individual threads have great strength, a good twist and no projecting ends of silk, only loops which have great strength and which give the fabric its softness and which fill in the points, making a very soft even surface.

In the ordinary hand-weaving with handspun thread, there is no object in having a fly shuttle loom or an improved pattern of any kind ; the best loom is the ordinary hand-loom in which the shuttle is thrown by hand ; for weaving greater breadths than 36 inches conveniently, we use a fly shuttle loom, the picking done by pulling a cord ; if the shuttle moves rapidly, it is certain to break the warp threads as they are not really even, and it is useless attempting to hurry the weaving if handspun thread is used for the warp. If millspun thread is used for the warp, it will of course pay to instal a really good fast loom of which there are many patterns, the Churchill loom of Ahmednagar being probably the best. There are considerable differences in procedure in weaving fine or coarse cloth and naturally much depends on the evenness of the thread. The best heavy fabrics are made by using for the warp fine thread of which two or more are twisted together. It is easier to make a fine thread even in spinning on the charka than to make a coarse one ; if such fine thread is woven direct, it makes very fine soft fabric, but it requires good careful weaving and is slow to weave. But if two, three or four of such threads are twisted together, the unevennesses average out and one gets very even strong thread, suitable for warp. In making bordered pieces, such thread should be used, as the threads especially must be thick to cover the white in the weft ; also if thick coloured warp is used to make the border, the same thickness must be used in the uncoloured centre or the centre will be very open owing to the close "beating up" of the weft being stopped by the thick border warp threads.

For weaving fine eri cloth from handspun thread, we use a reed of 20 to 22 dents, and this is the best for the cloth required by the Calcutta market ; for coarser thread a reed of 14 to 16 dents may be used.

It must be remembered that eri silk cloth, as usually made from handspun thread, does not shrink, but in time stretches a little ; this must be allowed for and it is one of the peculiarities of this cloth.

B. Millspun Thread.

Eri silk spun like waste mulberry silk is almost indistinguishable from the latter and can be used in the same way. We have used counts 160/2, 160/2, 280/2, but other counts are made.

Finishing.

Ordinary undyed cloth is 'finished' in a variety of ways, according to the appearance required. Ordinarily, the cloth is washed in hot water with soap and then dried and ironed. This leaves the colour unchanged. To get a whiter colour, the cloth is washed in boiling water and soap, then rinsed, put into water containing a little Sulphuric acid ; from this it is put into water and then again washed with soap or soda. To get a cream colour, the cloth is put into boiling water, then rinsed with Sunlight soap, and then, after rinsing, put into a weak solution of Citric acid or water containing the juice of limes, lemons or other acid fruits. A very good cream colour is also got by bleaching the cloth with Sulphur as described below. There are other methods used in the trade, some of which are secret and with undyed fabrics great importance is attached to proper finishing. A cream colour is generally required in India, as being the proper colour of the best eri silk.

We may draw attention to the very great value of boiling the cloth, in all processes, as this improves it very much. Eri silk improves very much by use and washing ; it is at first rough, coarse and dull-looking ; a great deal of this is removed by boiling the cloth in water with or without soap or soda ; it will not stand boiling with acid. A simple way of getting a good cream colour is to boil the cloth for one or two hours with $\frac{1}{8}$ of its weight of soap (bar soap) and then exposing to the sun for a few days. For ordinary small lots, any good hard soap may be used, but if large lots are to be done, it is best to get a good pure olein bar soap specially made for boiling-off silk.

Bleaching.

Though the cocoons are white at first, the silk becomes dirty in the course of boiling, spinning and weaving till in the usual course the silk produced is écru colour, a colour very suitable for use in this country, but not adapted to dyeing in light shades. Except for very special purposes, the colour does not matter; by exercising great care in boiling the cocoons, by washing them well after boiling or by prolonged soaking in water, by care in the spinning and weaving, a cloth can be got which is, after being washed, nearly white. To get the whitest, one must bleach. Very beautiful white thread can be produced by bleaching with Hydrogen Peroxide: nearly as white thread is produced by "blankit"; but the ordinary process of weaving is sufficient to again dirty the threads, and unless good weaving methods are used, the cloth will not be white. Cloth can be whitened by washing and exposure to sunlight for long periods. Tests have been made of bleaching with Aqua Regia and with Sulphur Dioxide (Sulphurous Acid). We recommend either of the following processes, but would emphasise the fact that such bleaching is not as a rule required. For those who wish to turn out high-class white or delicately dyed fabrics, the processes 1 and 2, though costly, will be of value, applied either to the thread or to the fabric.

(1). *Bleaching thread with "Blankit."*

Boil the silk for one hour in a solution containing ½ lb. Marseilles soap for 5 gallons of water. Wash thoroughly and put the silk for about 12 hours, with an occasional stir, in a solution of about ¼ to ½ lb. "Blankit" per 5 gallons of cold water. Rinse the silk in water which has been acidified by the addition of a little Sulphuric acid, then rinse in fresh water.

(2). *Bleaching thread with Hydrogen Peroxide.*

For 10 lbs. of silk take:

2—3 gallons commercial hydrogen peroxide.

3¼—4½ gills Sodium Silicate.

1—1½ lbs. white soap dissolved in 12 gallons of water.

This is warmed to 120° F. and the silk put in for several hours: at intervals it is wrung out and turned. When bleached, it is placed in water acidified with Sulphuric acid, then rinsed in fresh water. The bleaching liquid is used again, replenished if necessary.

(3). *Bleaching cloth or thread with Sulphur.*

Suspend the material in a closed chamber, after soaking it in soap and water; then burn sulphur in the chamber completely closed, so that all the oxygen of the air is combined with sulphur; keep the material in for 12 hours, then remove and wash well. The colour is not quite white, but rather cream colour.

Dyeing.

Eri silk, as other silks, is readily dyed with a large range of colours. The dyes may be classed as:

(1). "Natural" dyes obtainable from indigenous plants and used with mordants.

(2). Anthracene or Alizarin dyes, which are similar to the plant dye Madder but are made artificially and require mordants.

(3). Aniline colouring matters, which are applied direct, with acid or other agents, or which are "developed."

In the first and third classes there are dyes which are fast to light or to soap, or to boiling water, or which are fugitive to light or will not stand soap or boiling water. There is no inherent superiority in plant dyes over any others: some are fast to light, some fade very rapidly; but they were formerly obtainable in this country, their use was in many cases well known and, when properly applied, they give a good range and depth of colour. The prejudice in favour of these dyes is due to the fact that many aniline colours are sold and used which are not fast to light and it is rather the abuse of these dyes which has led to the general feeling that "natural" dyes are preferable to "synthetic" ones. Provided only fast aniline dyes are utilised, there is no objection to them and they have great advantages in ease of application, range of colour and delicacy of tint. The dyeing of silk is in many respects similar to that of wool, as opposed to the dyeing of

cotton; Watson has shown that silk is a better material with which to use indigenous natural dyes than is cotton, and silk is also a particularly good material with which to dye with many of the aniline colours. Some dyes require mordants, *i.e.*, the use of some substance to enable the colour to develop on the material, alum being a common one used. Indigo requires special treatment, since it is not soluble in water, and a soluble compound has to be produced, with which the silk is impregnated, and which on exposure to the air oxidises to indigo and is fixed upon the fibre. Aniline dyes (with few exceptions) require no mordant; some are applied with the addition of "boiled off liquor," *i.e.*, the liquid in which cocoons have been boiled to dissolve the gum, either a gum-soap solution or a solution of soda-gum or potash-gum, all of which act as an alkaline bath: this dye-bath usually requires the addition of either acetic acid, or sulphuric acid according to the dye used and the shade required; not more than 15 to 20 per cent. of "boiled off liquor" containing soap should be added or ten per cent. of liquor made with soda and its function apparently is to make the dyeing more even by making it slower.

The dyeing of eri silk is the same as that of other silks, *e.g.*, mulberry silk, and, since the fibre is white, the bleaching required for tasar silk is not needed. In fact, eri being itself pure white, takes dyes better than other silks if properly handled and kept clean. We have used the same methods for eri silk that are used for mulberry silk and there is no marked difference between the two in their behaviour towards dyes.

Method of dyeing.

There are three methods of dyeing, useful for different purposes. The cocoon may be dyed, the thread, or the piece of cloth. The last admits only of one colour, unless special methods of printing are used or unless the cloth is a mixture of cotton and silk or wool and silk. If it is desired to produce stripes, borders, checks, etc., with two or more colours, then the cocoon or thread must be

dyed. The dyeing of the cocoon must follow the boiling or the dye will not penetrate, and it is less economical than the dyeing of the thread. The cocoons should be carefully boiled in a cloth, well washed so as not to become entangled, and dyed at once in the cloth : if they are put into the liquid direct they get entangled and loose, making the spinning less easy. Cocoon dyeing with aniline dyes is rarely useful ; the dye fastens on the outside of the cocoon too much and the dyeing is uneven. With Alizarin or other mordanted dyes, this is not so marked as the mordant penetrates readily and the dye is more evenly developed through the cocoon. We do not recommend or use the practice of dyeing the cocoon. The arrangements for dyeing in this country are usually simple, and only small quantities are dyed at one time : no machinery is used and for our present purpose, the usual methods suffice. One must have a good water-supply, vessels that can be heated, measures for acids, etc., scales to weigh the silk, dye-stuff, etc.

Natural Dyes.

During the last fifty years, there has been a considerable amount published as to the dyes indigenous to India. To anyone who studies these it will be clear that the use of indigenous dyes varies much from place to place in the details of the processes used, but that there are certain principles underlying it which may not be known to the dyers but which are met by the many curious ingredients used in dye baths. It is useless to go into these and we give here a short summary of the more important dyes used, with the essential features of the processes. Whether alkali, for instance, is obtained from the ashes of one plant or another, or from earthy mineral alkali or from more or less pure alkali purchased in the bazaar, is a matter of local practice ; so with the use of lime-juice, tamarind or acids produced by fermentation. In many cases, it is known that the water of particular wells or rivers is useful in dyeing ; this is probably due to the presence of small quantities of either weak alkalies such as Sodium Carbonate or of such compounds as Glauber's salt

(Sodium Sulphate). We are not aware that the ingredients of such water have ever been investigated.

For dyeing eri silk, we would draw attention to lac-dye particularly. Lac-dye is extremely cheap, obtainable in more or less constant form and gives a very good fast colour. Indigo is also of special value. Beyond these, we do not think that there is any special value in indigenous dyes unless one can secure the very best professional dyers in a locality where dye-stuffs abound. As we are advocating the cultivation of this silk in the cultivated densely-populated areas and not in the jungles or hill-tracts, we do not attribute much importance to natural dyes, with the exception of the two mentioned. Great efforts were made in the past to stimulate the use of natural dyes; that was done to meet the growing competition of aniline and other synthetic dyes; since then, the former have been largely ousted, fewer people know the use of indigenous dyes, the dye-stuffs are not obtainable readily or in a pure form, and only in favoured localities, where dyeing still lingers as an indigenous industry, will the dyers be found who can get really good results with plant dyes. The synthetic dyes have also been greatly improved, and there is no reason why the softest and most beautiful tints should not be obtained with the exercise of far less skill and labour and at a smaller cost than was possible twenty years ago with aniline dyes or is now with plant dyes. Unfortunately, dyers use crude colours when they use anilines, and the soft tones of the plant dyes are not so often seen, but this need not be and it would be easier to teach dyers to obtain soft tones with anilines than to revive the general use of plant dyes. Where plant dyes can be got which are really fast and whose use is understood, they should be used; but we do not believe this can be said of any part of India but the forest or hill-tracts, save with such dyes as cochineal, lac, indigo, kamala, jackwood or myrabolans.

(1). Sapan Wood or Bakam. *Cæsalpinia sappan.*

An infusion of the wood yields a polygenetic colouring matter which with alum gives crimson, with tin salts a brighter crimson, with chromates a brown or purple, with copper sulphate a

claret brown, with iron sulphate a slate or claret colour. It is used to produce crimson. The colours are moderately fast.

(2). Kusum—Safflower. *Carthamus tinctorius.*

An infusion of the petals yields a yellow dye, not used; adding alkali produces a soluble "direct" dye which yields fugitive pinks or reds. It is used chiefly for cotton, and it is said that it was formerly exclusively used for Government red tape.

(3). Kamala. *Mallotus philippinensis.*

The dried powder in the seed capsules yields a red or yellow dye, soluble in alkalies and used with alum as a mordant. It is not fast, though widely used.

(4). Al. *Morinda tinctoria.*

The roots or root-bark yield a red dye, applied with Tannin or alum mordants to material usually steeped in castor oil emulsion. The colours are fast.

(5). Singrahar. *Nyctanthes arbor-tristis.*

The dried corolla-tubes yield a "direct" dye on infusion which dyes an orange colour.

(6). Manjista—Madder. *Rubia cordifolia.*

The infusion gives the same range of colours with mordants as is given by Alizarin, which is its artificially-made form. The dye-stuff is extracted from the dry roots.

(7). Lac-dye.

A colouring matter extracted from the body of the lac-insect (*Tachardia lacca, T. albizziæ, T. fici, T. decorella*, etc.) in the process of shellac manufacture by washing crude scraped lac in water (with or without soda) and precipitating the dye with lime or tin salts. The cloth is mordanted with alum or tin, and in some cases acids are added to the dye-bath. The colour produced is a deep or bright red, fast to light, washing, soap and alkalies. It is a specially good dye for silk, deserving of a much more extensive use. Mordanting with tin or alum, and using the dye with acid gives a

bright red, with alkali, a reddish purple; mordanting with iron and dyeing with alkali gives a grey. The red obtained with acids becomes purple-red if the material is washed directly in soap or alkali.

(8). Kanthal—Jakwood. *Artocarpus integrifolia.*

An infusion of the heart-wood yields a yellow colour which is fixed on cloth mordanted with alum and is fast to light, etc. It is stated to be much used in Burma.

(9). Annatto—Latkan. *Bixa orellana.*

The dried pulp of the seeds yields a bright orange dye, soluble in alkalis, applied to silk mordanted with alum. The colour is not fast to light.

(10). Dhak—Palas. *Butea frondosa.*

A decoction of the petals yields a yellow dye, fixed on alum-mordanted cloth, which is fast.

(11). Haldi—Turmeric. *Curcuma longa.*

An infusion of the rhizomes yields a yellow dye, which, with acid, is fixed on alum-mordanted cloth. Tin mordants make the colour orange. The colour is fugitive.

12. Indigo—Nil. *Indigofera* spp.

The leaves yield indigo-white, soluble, which on oxidation becomes indigo-blue. The dry powder is reduced, the fibre soaked in it and allowed to oxidise in the air. The blue colours yielded are fast to light, etc. Reduction is effected, on cotton or wool, with:

(*a*). Ferrous Sulphate and lime.
(*b*). Sodium Hydrosulphite and zinc dust.
(*c*). A woad, bran, madder and lime vat (fermentation vat).
(4). A potash, bran and madder vat (fermentation vat).
(5). A soda fermentation vat.
(6). A urine fermentation vat.

A method of dyeing eri silk is given below. (Reduced dyes.)

(13). Myrabolans. *Terminalia chebula*, etc.

Myrabolans, and other plant tissues which yield tannin (babul pods, galls, divi-divi, etc.) will on infusion yield a solution which on cloth mordanted with Ferrous Sulphate gives a durable black.

14. Cochineal. *Coccus cacti.*

Dried Cochineal insects ("German Grains") are extensively used for the very best silk dyeing in some parts of Bombay; the dye is made by pounding three parts of Cochineal and one part of Pista-ful (galls of *Pistachia vera*) and dyeing in the decoction. The red so extensively used for turbans in Western India is thus obtained. The dye is extremely fast to light, washing, perspiration, etc. It is now mainly produced from imported Cochineal, but the Indian Cochineal (*Coccus indicus*) grown in India on prickly pear has been used.

The above colours are combined to give shades and tints; *e.g.*, green is obtained from indigo and turmeric, violet from tannin iron and lac-dye, etc. It is in these combinations that the indigenous dyes are used in so complex a manner. The real art of indigenous dyeing lies in the use of these dyes in combination in a most complex manner, of which no one really good account exists. The practices of the best native dyers have never been really reduced to prescriptions on paper.

Reduced Dyes.

There are two dye-stuffs which require to be reduced in order to be obtained in a soluble form, the colour developing as the reduced (uncoloured) compound is oxidised in air on the fibre. These dye-stuffs are indigo, natural or synthetic, producing blues, and Helindon red, a synthetic dye, giving a peculiar lilac tint. Indigo is used in India for dyeing silk, in a variety of ways, just as it is used for dyeing other fibres, but we give a process for dyeing in detail because we have found that dyers accustomed to dyeing cotton or wool with indigo cannot in all cases do so in eri silk also. We are indebted for this process to R. V. Briggs, Esq., Calcutta.

INDIGO.

Strong Vat.

100 gallons	.. Water	..	500 litres.
2 lbs.	.. Average Indigo. ..	..	1,000 grs.
2 lbs.	.. Slaked lime (shell) ..	..	1,000 ,,
$\frac{2}{3}$-1 lb.	.. Zinc Dust (good quality) ..	..	300-450 grs.
$\frac{2}{3}$ gallon	.. Bisulphite of Soda. 57°T. ..	..	3,500 c.c.

Medium.

$1\frac{1}{4}$ lb.	.. Average Indigo	..	550 grs.
$1\frac{1}{4}$ lb.	.. Lime	..	550 ,,
$\frac{1}{2}$ lb.	.. Zinc Dust	..	225 ,,
$3\frac{1}{2}$ pints	.. Bisulphite of Soda. 57°T. ..	..	2,200 c.c.

Weak.

$\frac{1}{2}$ lb.	.. Average Indigo	..	250 grs.
$\frac{1}{2}$ lb.	.. Lime	..	250 grs.
4 oz.	.. Zinc Dust	..	113 grs.
$1\frac{1}{2}$ pint	.. Bisulphite of Soda. 57°T. ..	..	900 c.c.

Grind the Indigo to an impalpable paste with a little water, add the lime and add to about $\frac{1}{2}$ gallon to 1 gallon hot water (160°F.). Add the zinc dust to the Bisulphite and stir occasionally; let stand till no more smell of sulphurous aid is noticed (about $\frac{1}{4}$ hour). If after $\frac{1}{4}$ hour it still smells of sulphurous acid, add a little more zinc, as it shows the zinc is poor. Then add the Zinc-Bisulphite to the indigo, lime and water and stir. In about $\frac{1}{2}$ hour to $\frac{3}{4}$, the colour will have become yellow. This is stock solution.

Heat the vat and water up to about 120°F. and add to it $\frac{1}{2}$ pint bisulphite previously mixed with zinc. Then add the indigo stock solution, stir well, allow to stand and the vat is ready for dyeing. Wet the material with water, and wring it out; then put it in the vat and after ten to twenty minutes remove it, wring it out and let it oxidise for twenty minutes to half an hour. The number and duration of dippings must depend on the shade required. When this is obtained, wash the material in water and then in a dilute solution of Acetic Acid (1 in 500): then rinse and dry.

After several dyeings the vat will require "sharpening," *i.e.*, bringing into solution the oxidised indigo. This is done by adding one to two pints of Bisulphite reduced with zinc and $\frac{1}{4}$ to $\frac{1}{2}$ pint of milk of lime (20 lime in 100 water).

Yarn should be hung in the vat and turned occasionally, loose silk or cocoons in a net and the bottom of the vat should not be disturbed so as not to raise the sediment.

Helindon Red.

This is an example of a large class of dye-stuffs now being increasingly used which are extremely good but costly and difficult to use. Two parts of Helindon Red powder are mixed with twenty of water and three of soda lye (77° Tw.), and two parts of Hydrosulphite concentrated powder. The whole is kept at 120°F. well stirred till it becomes yellowish ; then add it to the dye-bath, and dip the silk into it lukewarm. Keep it in twenty minutes, wring out and let the dye oxidize in the air. The depth of shade is regulated by the number of dippings. (M.L.B.)

Anthracene (Alizarin) Dyes.

Alizarin is the colouring principle of the madder root and, while it does not itself dye fibres, with different mordants it yields a variety of colours which are extremely fast to light, soap, etc. There are several chemical compounds, allied to Alizarin and produced synthetically from Anthracene, which are commonly termed Alizarin colouring matters. These are obtained from firms manufacturing these dyes who give instructions for their use and prepare them for each tint required. We include in this class Cœrulein, Gallein and allied dye-stuffs which require mordants.

The Badische Anilin and Soda-Fabrik issue a shade card of forty tints produced by these dyes with alum, chrome-alum or chloride of chrome, mordant. Using Alum, Soda and Bicarbonate of Soda (all readily obtainable), the procedure is as follows :—

Put the silk over-night into 60 pts. alum ⎫ Per 1,000
6 ,, soda crystals ⎭ parts water,
squeeze, wash well in water and pass for $\frac{1}{4}$ hour through Bicarbonate of Soda (·5 per cent. in water), wash. Dissolve the dye in water, add one part of Acetic Acid per 1,000 parts of water, and

wash the silk in this cold bath for $\frac{1}{4}$ hour ; heat to boiling in $\frac{3}{4}$ hour. Wash, soap and brighten with Acetic Acid.

With this method alone, a range of colours is obtained including scarlet, crimson, orange, yellow-green, salmon-pink and three shades of purple. To obtain other shades, one must use Chromium Chloride mordant; put the silk into Chloride of Chrome 20° Be. for 4—6 hours, wring out and wash well in running water. Pass for $\frac{1}{4}$ hour through a bath containing 5 parts per 1,000 of Bicarbonate of Soda, wash well and dye with Acetic Acid (1 part per 1,000 parts of water) as with alum above. (B.A.S.F.) Alizarin dyes are not usually sold in this country and can be imported in 28 lb. bags. Other Alizarin dyes are dealt with as follows :—

Dissolve 6 parts of alum or Sulphate of Alumina in 10 parts of water and precipitate the solution with 4 parts of Sugar of Lead and 2 parts of Nitrate of Lead previously dissolved in water. Let the precipitate settle, draw off the liquor, dilute to the proper degree. Mordant in this as above, then dye as above ; Alizarin Orange N. paste gives an orange, Cœrulein paste an Olive green, Alizarin Red No. 588 and Alizarin Red P. S. two shades of red (M. L. B.)

Alizarin can be purchased in India in lump form at 10%, 20%, 40%. With this several shades can be obtained with various mordants. Short directions are given for the production of these shades, and we may add that the colour produced with Bichromate and Sulphuric Acid is an extremely good grounding colour for obtaining browns, purples, etc., by dyeing with acid dyes after the Alizarin. It is also an excellent colour by itself. For Alizarin 40%—

1. Claret Red :

   Mordant with 6—10% Alum Sulphate.
   5—8% Cream of Tartar.

   Put in cold and raise to boiling.

   Wash and dye in 5% Alizarin and 4—6% Acetate of Lime or Air-slaked Lime.

   Wash in cold, then raise to boiling.

2. Orange Red:

   Add 1—4% Stannous Chloride and 1—4% more Tartar to above Mordant-bath.

3. Orange:

   Mordant in 5—8% Stannous Chloride and 5—8% Cream of Tartar.

   Dye with 5% Alizarin without Lime.

   Adding 4—5% Acetate of Lime makes the colour more red.

4. Claret-brown:

   Mordant with 3% Potassium Bichromate.
   1% Sulphuric Acid (168° Tw.).

   Adding Calcium Acetate to dye-bath makes colour more blue.

5. Blue:

   Mordant with 4—8% Ferrous Sulphate.
   4—8% Cream of Tartar.

   Dye with 5% Calcium Carbonate and 5% Alizarin.

With the exception of the reduced dyes, and of such natural dyes as lac-dye, there are practically no dyes to equal the above in fastness to light, to water, to washing, to alkali (street dust), to acids (perspiration or fruit juice) or to all forms of treatment. They are incomparably the best but their use is difficult. For dyeing thread or cocoons for putting into borders for dhotis, for dyeing any form of cloth that is to be worn out of doors, these dyes should be used exclusively if possible, as they are used at present in this country for Turkey Red dyeing on cotton.

Aniline Colours.

There are a very large number of these compounds used in dyeing; many are used in silk-dyeing because of their ease of application and because delicate fabrics do not last so long that the fastness of the dye matters. We have endeavoured to eliminate the most fugitive dyes, but it must be remembered that a dye fast

to light may not be fast to boiling water or to soap. This is often immaterial as curtains, for instance, would not be cleaned in boiling water but in tepid water and soap, so that for curtains a colour fast to light and to soap would be required.

Another point to consider is whether thread dyed with a colour will, when woven say with a stripe of another colour next, stain the neighbouring material on being washed. Some dyes "bleed," *i.e.*, come off to some extent with soap and dye the fabric; this is a defect which must be taken into account when dyeing cocoons or yarn to be used with other colours. Other points are the fastness of the colour to acids (*e.g.*, fruit juice) or to alkalies (*e.g.*, street dust). In ordinary practice with handloom and simple dyeing methods, there is a danger that coloured warp threads, in the process of sizing, will bleed into white or other colours in the warp. To avoid this occurring, dyed material should after dyeing be placed in a solution of Tannin (8%) obtained by infusing myrabolans 24% or babul pods in water and then in a bath of 4% Tartar Emetic; or the dyed material should after brightening be washed with soap or well washed and wrung in a soap solution. Soap removes the superficial dye that, in sizing, bleeds on to the sizing brush and so on to white or other threads. We have found the Tannin treatment extremely successful with such dyes as brilliant orange, which bleed very much and Tannin is so easily obtained in this country that this treatment should be followed.

No attempt is made here to class the colours in groups according to chemical composition and we have not attempted to deal exhaustively with them. Starting with the ordinary silk dyes of commerce, we have tested and eliminated many and here mention such as we believe to be good dyes giving a large range of shades, so that the dyer may have a considerable choice without having to resort to dyes of whose fastness he knows nothing. The number of dyes is large, the number of names they pass under is much larger but those mentioned below are satisfactory and have been tested. We have not attempted to deal exhaustively or even

completely with the whole subject, only to find a sufficient range of really good dyes.

The Aniline Dyes are grouped as follows:—

(1). Acid Dyes, requiring an acid bath for fixation.

(2). Mordant Dyes.

(3). Basic Dyes, requiring a neutral or weakly acid bath.

(4). Dyes of the Eosine Group or Weakly Acid Dyes (omitted here).

(5). Substantive or Direct Dyes, which dye cotton direct and are used for silk with Glauber's salt or acid bath.

(6). Diazotised or Developed Dyes, which are substantive dyes fixed and developed on the fibre by diazotising.

(7). Dyes soluble in Spirit or Acetine, not soluble in water (omitted here).

Acid Dye-Stuffs.

These dye-stuffs are used with a sufficient quantity of acid not only to neutralise the boiled-off-liquor, if such is used, but to make the bath distinctly acid. Either Acetic or Sulphuric Acid is used or both.

For 5 lbs. of silk, add one gallon of boiled-off-liquor (soap solution) and 1 lb. of Acetic or $\frac{1}{2}$ lb. of Sulphuric Acid to 20 gallons of water, warm; put in the silk, turn and wash it and wring it out; add the dye-stuff dissolved in water, taking say $\frac{1}{2}$ or 1 per cent. at first only. Put in the silk again, turn and work and wring out; heat the bath to nearly boiling, put in the silk, and work it for half an hour, adding more dye-stuff if required. When done, put the silk into cold water, acidified with Acetic or Sulphuric Acid and then wash well. For some dyes, "break" the boiled-off-liquor with Acetic Acid till it is sour, then add it to the dye-bath and add enough Sulphuric Acid to make the bath really acid. For others, no boiled-off-liquor but add enough Acetic Acid to the plain bath to make it acid and dye in that. (Orange II, Fast Red, Flavazine, etc.). Acid dyes are suitable for silk in many

cases owing to their level dyeing, ease of application and beautiful tints; they are far faster than basic dyes, and only inferior to the Alizarin or developed dyes; in many cases they bleed into white fabric or are washed out in boiling water or soap.

As a rule from one to three per cent. of the weight of the silk gives a full shade, and if the dyeing is finished at a sufficiently high temperature in the presence of enough acid, the dye should all be fixed on the fibre, the bath should be clear and exhausted and, on washing the dyed material, the dye should not wash out. If insufficient acid is present, the dye is not fixed, it comes off on the fingers, it washes off in cold water and the fibre is not dyed but simply stained. Equally if the temperature is not high enough at the end, the dyeing will be uneven. We recommend the novice to begin by using small percentages of dye and adding more dye solution to the bath till the tint is right, removing the silk every time the bath is heated up or the dye-solution added. The greatest possible care must be taken in washing out the acid from the dyed silk in plenty of water. When dyeing in a simple manner without washing appliances, one tends to do the washing-out of the acid too rapidly or in insufficient water, with the result that the acid concentrates by evaporation, is held by the fibre and destroys it. Dyed cocoons or thread should be very thoroughly washed out in running water or many changes of water.

2. Mordant Dyes.

For khaki shades and some other very fast ones, the mordant dyes used for wool should be employed, as they are extremely fast and very easy to work. A simple method is to use the Metachrome mordant with the dye and boil all together for two hours.

For an average shade of khaki we weigh out the following, based on the weight of silk to be dyed:

Metachrome Mordant	3%.
,, Brown	1%.
Cyprus Green	0·05%.

The water is boiled with the cloth and mordant; the cloth is then removed, the dyes in solution put in and the cloth replaced; the whole is then kept at the boil till the dye-bath loses nearly all its colour (about one hour) and then for one hour longer to thoroughly fix the dye.

3. Basic Dyes.

For 5 lbs. silk, dissolve the dye-stuff in 20 gallons of water, add 9 to 10 oz. of Acetic Acid (9° Tw.) heat to 140° F. and dye in this bath for half an hour, or, if boiled-off-liquor is used, add enough Acetic Acid to make the liquor sour and then dye. A large number of dyes are included herein which are often fast to washing but usually not to light. These dyes can also be made faster to water by passing into a bath containing 8% of Tannic Acid (24% Myrabolans), if necessary fixing after in another bath of Tartar Emetic (4%). Basic dyes are largely sold and used in India, because no acid or other assistants are required; a simple solution in water is enough to dye silk in many cases, though the colours are not fast. For the Alkali blues there is a special process :—

Dissolve the dye in water and add 4% of Borax; heat to 112°F., put in the silk and heat rapidly to nearly boiling and keep for ½ hour. Take out the silk, wash it, and put into a bath of water containing 5% of Sulphuric Acid. The acid precipitates the colour on the silk, which is then dyed. The Alkali blues are used especially for light blue shades.

Another process is to dye them in a boiling bath containing simply boiled-off-liquor, or a little Alkali, such as soda crystals, such a bath being slightly alkaline and not neutral. It is used for some blues. In place of Alkali, Marseilles Soap is used (½ oz. per gallon of water) as below for Nitrosamine Red in paste.

4. Substantive or Direct Dyes.

For 5 lbs. of silk, take 20 gallons of water, dissolve in it the dye-stuff, add ½ lb. of Glauber's salt and dye for ½ hour at the boil after adding a little Acetic Acid, or dye in a bath containing boiled-

off-liquor, broken with Acetic Acid. When dyed, place the silk in a fresh cold bath of water containing ½ lb. of Acetic Acid in 45 gallons and dry without rinsing.

For Nitrosamine Red in paste. For 10 lbs. of silk, take 1 lb. of Marseilles soap, 2½ lbs. Nitrosamine paste, 45 gallons water; dissolve the paste and soap in the cold water, put in the silk, heat slowly to boiling and boil for ½ hour without bubbling; wring out the silk, and brighten in a bath of hot water 45 gallons containing 1 lb. of Sulphuric Acid. It gives a yellow tending to orange.

For the Chicago Blues (B. A. Co.) the following process is used: Dye as above; rinse and put the silk for 20 minutes into a fresh boiling-hot bath of 1 to 3% Bluestone and ½ to 1% Acetic Acid 30% in sufficient water. (These percentages are calculated on the weight of the silk as usual.)

5. Developed Dyes.

First dye the silk with a direct (substantive) dye as above. Then prepare a diazotising bath as follows: in 150 gallons of water dissolve 2 lbs. 11 oz. of Nitrate of Soda and to this add slowly 5 lbs. of Sulphuric Acid (strongest). The silk is put into this bath for ¼ of an hour, quickly rinsed in cold water and placed in the following developing bath:—

On 1 lb. of Beta-Naphthol pour one lb. of soda lye (75° Tw.), and while stirring very well add five gallons of hot water and then sufficient cold water to make up to 550 gallons.

In this bath it is washed for ¼ hour, then rinsed and dried. If one wishes to develop with soap, put the silk after the first bath into a warm soap bath (2 lbs. per 20 lbs. of silk), turn a few times and wash. The bath should be 120° F.

Sulphine (Primuline) diazotised and developed with soap gives a yellow (old-gold shade), with Beta-Naphthol a crimson, with Oxamine developer a deep red; Oxamine blue with Beta-Naphthol gives a deep blue, with Oxamine developers violets, as does also Oxamine Violet. (B.A.S.F.) With Beta-Naphthol, Zambesi Blue

4B, gives a sky blue, Naphthogene Blue R a navy blue, Naphthogene Blue 4R a reddish blue, Zambesi Indigo Blue R a dark blue. (B. A. Co.). The Sulphine dyes are usually faster than the Oxamine dyes.

CHOICE OF DYES.

The question of dyeing is at first a very complex and difficult one for several reasons. Indigenous plant dyes are in some cases good, their use is well known to professional dyers and they can be obtained in the bazaars. But they are not easy to use, nor obtainable very pure ; when the services of professional dyers are obtainable, then the use of good vegetable dyes is sound. The range of colours is small, the colours are often dull and some of the best (*e.g.*, Annatto) are very fugitive to light. In every Indian bazaar are now to be found Anilin dyes, sold indiscriminately without regard to fastness to light or to water, used often carelessly and with curious methods and giving extremely crude colours that run into each other when woven side by side. Apparently Indian dyers and people generally have found bright colours to their hand, found them easy to apply so as to get results better than with their plant dyes and have used them to the exclusion of their natural dyes, often badly and crudely, producing very poor results. On the other hand, their intelligent use is not easy ; there are numerous firms selling these dyes, each firm giving fancy names to their own products, all competing and all selling fugitive as well as faster dyes. If the demand exists now, it has certainly been made and had these firms confined themselves to the better dyes, used a uniform nomenclature and put out their wares suited to a few processes easily mastered, then there might have been a possibility of the use only of the high class dyes on a proper system.

When one then gets into the complexity of acid, basic, neutral, direct, mordanted, developed, Alizarin and other dyes, one can understand how it is that the use of the most easily applied basic

(fugitive) dyes has become so general. We believe that the wisest course to recommend is :

(1) The use of either (*a*) good acid dyes fast to light ; (*b*) direct or substantive dyes or (*c*) Alizarin dyes, where one simple method is wanted, adhering throughout to one group, the acid dyes being the simplest but the least fast of the three groups.

(2) The use of indigenous dyes by professional dyers when such can be found.

(3) The use of only Alizarin dyes or of Alizarin dyes with acid dyes, where dyeing is done on any scale and the use of these dyes can be adopted.

If any industry in eri silk by firms, as apart from individuals, is being undertaken, we would recommend the use of the Alizarin dyes so far as possible but if not, then only of the best acid or direct dyes used intelligently. In this connection it is perhaps not unreasonable to suggest getting advice as to which dyes are fast and their manner of application, adhering to the products only of one firm and using their directions. There are firms producing dye-stuffs and selling them in this country who will give assistance to those who really want to use only fast and reliable dyes. We cannot advertise the wares of any firms ; we give below a list of some of the dye-stuffs sold in India which are, in our opinion, good for dyeing eri silk for all ordinary purposes, though they are inferior to the Alizarin colours. There are a host of tints and shades, of course, which cannot here be discriminated but advice as to obtaining particular colours is easily obtained.

RED.	*Direct Dye-stuffs.*	Thiazine Red G.
		Columbia Fast Scarlet 4B.
		Cotton Red 4B.
		Brilliant Congo R.G.
		Aceto purpurine. 8B.
	Diazotised.	Berolina Fast Red.
		Sulphine with Oxamine developer.
	Acid Dye-stuffs.	Azocardinal.
		Azo-Coccine 2R.
		Sorbine Red.
		Naphthol Red S.

ORANGE.	*Direct Dye-stuffs.*	Cotton Orange G. R.
		Pyramine Orange 3G.
		Congo Orange R. G.
		Mikado Orange.
YELLOW.	*Direct Dye-stuffs.*	Cotton Yellow R.
		Chrysamine G. R.
		Chrysophenine G.
		Curcumeine S.
		Columbia Yellow.
	Diazotised.	Sulphine with Soap.
	Acid Dye-stuff.	Azoflavine.
		Acid Yellow G. R.
		Azo-Acid Yellow.
		Curcumeine extra.
		Tartrazine.
		Flavazine (Acetic).
		Brilliant Yellow S.
		Fast Yellow extra.
		Fast Mordant Yellow G.
GREEN.	Get by combination of blue and yellow, *e.g.*, Tartrazine and Silk Blue.	
	Acid Dye-stuff.	Diamond Green.
BLUE.	*Direct Dye-stuffs.*	Chicago Blues, developed with bluestone.
	Diazotised.	Naphtogene Blue 6B.
	Acid Dye-stuff	Silk Blue B.
		Water Blue 6B.
		Induline N. N.
		Soluble Blue.
		Indocyanine B.
		Cyprus Blue R.
	Basic Dye-stuffs.	Alkali Blue with Borax (for light shades).
VIOLET.	*Direct Dye-stuffs.*	Columbia Violet R.
	Acid Dye-stuffs.	Acid Magenta S.
		Acid Violet 4R-7B.

The great number of Anilin Violets, especially the basic ones, are not fast to light; the shades are best got by combination of acid dyes, if Alizarin dyes cannot be used.

PINK.	*Direct Dye-stuff.*	Erica.
	Acid Dye-stuffs.	Rh[illegible]eine. } Mauve-pink, not fast to light.
		Rhodamine R. } Mauve-pink, not fast to light.
		Resoline G. } Mauve-pink, not fast to light.
BROWN.	*Direct Dye-stuffs.*	Thiazine Brown G. R.
		Zambesi Brown G.
	Mordant Dye-stuff.	Metachrome Brown.
BLACK.	*Direct Dye-stuffs.*	Zambesi Black.
		Oxamine Black.
	Diazotised.	Zambesi Black.
		Oxamine Black.

	Acid Dye-stuffs.	Janus Black D. Black-Black. Balatine Black. Silk Black. Ethyl Black. Wool Black.
LILAC.	*Reduced Dye-stuff.*	Helindon Red.
SAGE GREEN.	Use Diamond Green and Mikado Orange or another Orange.	
MAROON.	*Scarlet.* *Brown.* *Violet.*	Combined to the right tint.

With a selection of the above dyes, and by judicious combination, almost any tint can be obtained. There are difficulties in getting such tints as green, brown, heliotrope, mauve, olive-green, unless one experiments with mixtures, either dyeing with a bath of two mixed acid dyes or by grounding with one dye-stuff and topping with another after. For securing deep shades the Alizarin dyes as grounding dyes followed by acid dyes are often useful. The fastness to light of two dyes together is not the same as that of each separately nor will the colour simply fade but will change, as one tint fades out faster than the other. This is true also of fastness to water; thus one can get beautiful lilac shades with Erica and Silk Blue; but on washing, the blue goes out, not the pink. One must therefore experiment. Dyeing is not a difficult matter if one restricts oneself to one class of dye-stuff; it becomes a very technical and complicated business if one wants to dye with all dyes, or to dye mixed fibres (*e. g.*, cotton and silk), or to dye all classes of fabric (cotton, wool, silk, linen, etc.). But if the object is to produce simply dyed eri thread or cloth, there is no difficulty in the matter provided only one class of dye-stuff is used. Anyone can use the acid or the direct dye-stuffs; good results can be got and with no special technical skill. The colours can be readily blended, or used in varying strengths and with the information supplied so readily by dye-stuff producers, there is no inherent difficulty. We have endeavoured to simplify the matter above and to recommend only fast dyes; naturally good results will not be got by buying up any anilin dyes in the bazaars and using them, as is so often done, in very curious ways. But if one selects

the best, uses them according to the instructions given and exercises ordinary care, good results are easily obtained. Dyeing as practised by dyers who dye all classes of fabrics, who dye wool, cotton and silk separately or mixed, who print colours, who use "resists" and "discharges," and who must be able to turn out immense quantities of material to exactly even shades is, of course, a highly technical business; but to dye cocoons or yarn so as to get stripes or checks or coloured borders, or to dye in the piece, each piece separately or a few at a time is no difficult business and it is from that point of view we have discussed it above.

N. G. Mukerjee states that in the Rampur Boalia Sericultural School the dyes sold as Maypole Soap have been used in silk-dyeing, giving very showy results and very beautiful shades. These are mixture of dyes and salts, which dye direct in boiling water. The "Dolly Dyes" act in the same manner and a large range of colours are obtained very simply which, for dyeing on a small scale without regard to very great fastness to light, are quite satisfactory. These dyes are, in some cases, at least, substantive dyes with Glauber's salts and for dyeing on any but a very small scale are more expensive than purchasing the pure dye and requisite assistants.

We have been dyeing thread, cocoons and cloth constantly in Pusa, since we commenced weaving and we have now adopted one class of dye only, as being suited to our purposes and as being the best process for eri silk dyers who can use only ordinary appliances. We have abandoned the indigenous plant dyes, as the skill required to use them is very great and we have not employed a skilled dyer; (where there are such dyers, they should be employed). We have found Alizarin dyes very good but, with simple appliances, not satisfactory for more than a few shades; (they are suited only to dye-works and not to small dyers). We have abandoned diazotised dyes as being beyond the reach of the ordinary producer; and we have adopted a limited number of the acid and substantive dyes fast to light and to bleeding, all of which we treat with Tannin

and antimony after dyeing. The only addition is the mordanted dyes for khaki shades (single-bath method with Metachrome mordant or after mordanting with chrome), which may also be used for a limited range of shades of very great fastness, lac-dye for certain red shades and Alizarin with chrome or tin mordant for brick red or deep red.

The dyes used are the products of two firms sold in India; enquiries were made from the trade through the Chamber of Commerce, Bombay, and we believe these dyes to be suitable to ordinary purposes. Unless very exceptional fastness is required (*e.g.*, dhoti borders) anyone wishing to produce dyed thread or fabrics will do well to use these dyes or similar substantive or direct dyes, of which there are other brands than those mentioned but which must be fast to light, fast to sizing and fast to bleeding into white silk.

The process of dyeing as we do it is simply as described above with Acetic Acid or Sulphuric Acid, with or without boiled-off-liquor, and with an after-treatment in Tannin and Tartar Emetic. The silk after dyeing is rinsed in water and put into three gallons of warm water containing one ounce of Tannin or two ounces of Tannin Extract or Myrabolans. After an hour it is well rinsed and turned in a bath of three gallons of cold water containing half an ounce of Tartar Emetic. It is then brightened in a weakly acid bath, washed and dried.

The following dyes require Sulphuric Acid:—

Azo-Coccine 2R.	Naphthol Red S. G.
	Sorbine Red G.
Azo-Cardinal G.	Palatine Scarlet A.
Cloth Red G.A.	Azocarmine.
Cloth Red 3 G. A.	Tartrazine.
Acid Yellow G.	Soluble Blue.
Azo-Acid Yellow.	Victoria Blue B.
	Silk Blue B.
Water Blue 3B.	Ethyl Black.

The following require Acetic Acid:—

Brilliant Congo R.	Thiazine Brown R.
Aceto-purpurine 8B.	Cotton Yellow G. I.
Columbia Fast Scarlet 4B.	„ Orange G. R.

Erica 2N.	Pyramine Orange 3G.
Salmon Red G.	,, Yellow G.
Mikado Orange 4R. O.	Cotton Brown R. V.
Chrysophenine G.	Oxamine Brown M. N. I.
Columbia Yellow.	,, Violet.
Curcumeine S.	,, Black.
Columbia Violet R.	Diamond Green G.

Any firm of dye-producers can match these dyes with identical or similar products of equal value; but it is not easy to get dyes which have a good fastness to light, sizing and bleeding, and which will dye silk; the enquirer who is not satisfied with the above should go in for wool-dyes fast to light acids, etc., or for Alizarins. For the producer of dyed fabrics on a small scale, wishing to use few chemicals and work on simple basis, we recommend the above dye-stuffs.

Columbia Fast Scarlet.	A warm bright crimson, light.
Azo-Coccine.	A bright crimson, with good depth. The nearest to scarlet.
Brilliant Congo R. G.	Dull crimson, tending to brick red.
Salmon Red G.	Clear dull red, tending to brick red.
Aceto-purpurine.	Bright red with a touch of mauve, less purple than fast red.
Cloth Red G. A.	Deep crimson with a touch of brown, no blue. Like lac on tin mordant.
Naphthol Red S. G.	Deep red with a touch of mauve like aceto-purpurine but redder.
Sorbine Red G.	Pure bright crimson.
Pyramine Orange 3G.	Orange tending to brown, no red.
Mikado Orange 4 R. O.	Deep orange red tending to salmon red.
Curcumeine S.	Yellow to orange, less brown than curcumeine extra.
Chrysophenine G.	Yellow to dull orange, no red.
Columbia Yellow.	Dull " old-gold " shade.
Azo-Acid Yellow.	Dull yellow, nearly " old-gold "; yellower and with more body than the last.
Acid Yellow G.	As the last.
Tartrazine.	Clear pure lemon-yellow, no orange.
Acid Yellow R.	Yellow orange, almost the same as pyramine orange 3G.
Cotton Yellow G. I.	Pale " old-gold " yellow, little body.
Thiazine Brown R.	An orange-brown, little red.
Oxamine Brown M. N. I.	A deep full umber-brown.
Indocyanine B.	Deep blue, dull, touch of indigo.
Soluble Blue T.	A very rich opal blue, bright.
Silk Blue.	Deep pure blue; in weak dyeings with boiled-off-liquor gives pale blue.
Water Blue 3 B.	A clear bright blue.
Ethyl Black 4 B. F.	A deep black tending to purple.
Columbia Violet R.	Purple-red, like lac on alum, dull.
Oxamine Violet R.	Deep rich purple, tending to blue.

V. THE CASTOR PLANT.

Castor Varieties.

All the varieties of castor we could obtain in India are eaten by eri silk-worms, and we have not been able to find any one variety better than another from their point of view. We have grown all the obtainable kinds of castor and have tried to pick those most productive of leaf. We have been unable to get any botanical classification of castors but this is in progress in South India. We rejected as unsuitable all the small leafed dwarf plants, such as the small *endi* of Surat; all the perennial varieties we obtained came down to six apparent varieties. The local Bihar varieties are all green or red stemmed with a white waxy covering on the stem and leaf-stalks; there are also brilliant green and red stemmed varieties with no wax; and we found in two lots (*Arend* of Cawnpore and *Thota Ahmedali* of Madras) a giant red or green variety with wax. We have, therefore, on mere appearance, habit and size separated out:

1. Green with wax.
2. Red ,, ,,
3. Green without wax.
4. Red ,, ,,
5. Giant green with wax.
6. ,, Red ,, ,,

The commonest varieties are both green and red with wax; amongst the plants collected at Pusa, the red and green without wax were found mixed, and are the best leaf-yielders of the varieties we have tested, but there is not a very marked difference and it would seem best to cultivate the local variety of perennial castor and not to attempt to introduce a special variety. We are testing the giant castor of Abyssinia, but until the varieties have been properly separated and the matter reduced to an accurate basis, any work with

castor varieties must be inaccurate. The question of leaf diseases of castor is also under investigation by the Imperial Mycologist; apparently the green stemmed variety without wax is liable to disease and so unsuitable.

It is essential to have the castor near the rearing house or the rearing house in the castor field and the usual method whereby a little castor is sown with other crops or on bunds, does not provide enough castor near at hand for rearing on a large scale, though it does so for cottage cultivation.

Also it is doubtful if growing pure castor is as profitable as growing castor with a ground crop such as sweet potatoes. With perennial castor one must sow wide apart, at least six feet between rows and plants; with closer sowings the plants run up and can scarcely be plucked at all. For leaf one wants a bushy plant, and it is useful to remove the leading shoot when the plants get four feet high.

It is absolutely essential for continuous rearing to have young leaf for the young worms; in Bihar a proportion of the plants should be cut down in February to provide young leaf in April-May to get the best results, one must bear this in mind and adopt the local practice of castor cultivation accordingly.

Yield.

Three-quarters of an acre of land yielded 45 maunds of leaf and eight maunds of seed. It was sown in April on irrigation, suffered heavily from caterpillar and was in the ground 9 months. Two acres yielded 160 maunds of leaf, 21 maunds 8 seers of seed and some more as a second crop. It was sown in October 1907, stood till January 1909, a total of 16 months.

Other Food Plants.

We have not found any other food-plant on which the insect can be properly reared; in Assam other food is used to keep the stock alive through the rains but this is not desirable, as seed is now obtainable so easily.

The Manure.

An acre of castor yields approximately 100 maunds of leaf of which about 30 maunds is turned into excrement and 30 maunds is waste leaf. The former when dried is a manure that should, according to the Imperial Agricultural Chemist, be applied at the rate of 4 maunds per acre. The latter is suitable as a green manure. In estimating the value of these as manure, the fact must be remembered that the excrement has been partly digested.

ERI SILK AS AN INDUSTRY.

In a previous section we have discussed the climatic conditions under which eri silk can be grown and in considering the possibilities of eri silk cultivation in any locality one must first consider this. In Assam, eri silk is grown from October to March mainly; one reason why it is not grown in the rains is that castor does not thrive then, another is that the parasitic fly is active then. In Lower Bengal, eri silk can be grown at all times so far as the climate is concerned. In Bihar, the worms thrive and grow rapidly from June to November; there is then a slow winter brood and the following broods in March, April and May are liable to suffer from the extreme dry heat. In the United Provinces this is still more marked and it is better to cease rearing altogether for April and May, as the trouble of keeping the rearing houses moist is considerable. Good broods of cocoons have been obtained in the Punjab and Central India, but the long winter and longer period of dry heat make the cultivation unsatisfactory. In Kathiawar and Gujarat, broods are obtained throughout the year except when dry hot weather prevails but the climatic conditions are suitable for about 10 months, the winter being so mild that the broods then are but little prolonged. From reports received from rearers, the West Coast and Malabar are well suited to the rearing throughout the year and much of South India is well adapted to it. The Deccan is too hot and dry in March to May but good broods are got at other times and, with some care, throughout the year. In the Central Provinces, rearing has been done only in Chanda and Beetul, but there successfully, and a great part of the Province is suitable.

The next consideration is the supply of food; it is probable that the quality of the leaf is the important factor in disease, but we do not know enough as yet to say what quality of leaf is dele-

terious. Mr. C. M. Hutchinson has found by enquiry in Assam that the rearers regard leaf that has been grown quickly, say after pruning in warm moist weather, as unsuitable, perhaps because of its high moisture content. On the other hand, very old leaf is probably not suitable and one of the greatest difficulties seems to lie in regulating the leaf-supply. I am inclined to believe our outbreaks of disease were in part due to too heavy plucking followed by a production of new leaf which we used for feeding and we have undoubtedly not regulated our broods to our leaf-supply. So far as can be seen the art lies in maintaining sufficiently large broods to use the leaf regularly and to pluck all full-grown leaf before it gets old but not to have to strip all the leaf at any one time. That is, for one acre of castor, six regular broods of 30,000 worms is better than irregular broods with one big one. With only one lot of plant, one must of course start with a small brood when the plants are young, but if one grows perennial castor and one crop overlaps another by three months (July to October) one can have regular even broods. This question is so much a matter of local conditions that it must be considered for each place and it is essentially one to be taken into account. The final consideration is the organisation of the industry. In Assam, the industry is already organised; there are centres for the disposal of cocoons, for buying seed, for selling yarn or cloth. Elsewhere there are not and in Tirhoot, for instance, hundreds of rearers have given up for want of a market for cocoons. There is a demand for cocoons in Calcutta and Bombay; but some organisation must be formed to put the small grower in touch with it. At the outset that organisation must be created and the natural organisation is a Zemindar or landowner able to purchase and hold small lots of cocoons or cloth and sell in large lots or able to arrange for the purchase of cocoons at fairs or markets. The Silk Mills in Bombay, for instance, do not care to buy smaller lots than 300 or 500 lbs. The carriage to Calcutta of small lots of cocoons is too heavy. So also for cloth; there is only a local market for small lots but other markets for large lots.

The industry is one that depends on the presence of a buyer of small lots and as things are now, there is an assured market for large lots of cocoons. We find that cocoons can be reared in large rearing houses at Rs. 25 per maund of 82 lbs., paying for all our labour at from two to four annas a day. Such cocoons are selling now at from Rs. 60 to Rs. 80 so that there would seem to be a good margin for the middleman; the small rearer doing the rearing in his own house will not pay for labour as a rule so that a return of Re. 1 per seer should induce him to go in for it. In Assam, the rates paid fluctuate from 12 annas to Re. 1 per seer, depending on the quality of the cocoons, the large white fetching most, the brown least. We have eliminated the brown cocoons and all the seed we send out gives white cocoons.

We are opposed to large rearing houses and believe that rearing in small lots by cultivators is the best, as is done in Assam. In Gujarat and in Tirhoot, it is found that an obstacle is the carelessness of the people themselves, insufficient feeding producing poor cocoons; this is not universal but there is a tendency to it and in some localities it may be so ineradicable as to kill the industry. During the last year, we have trained a number of men in rearing, etc. To all we point out that it is useless going in for the industry unless they can sell cocoons or cloth and we have people come to Pusa thinking that they have only to learn and then we will make them well-to-do. But it is necessary to begin at the other end and, before coming, to consider if, in the locality in which it is intended to start, there is any likelihood of getting a sufficient volume of cocoons to be saleable.

With regard to cloth, it is quite clear that it is more profitable to get cocoons spun and woven if a good quality of cloth can be made which will find a market. This means organisation; it means giving out the cocoons for spinning; it means getting back thread and getting it woven into good even cloth suitable for the market. That this can be done where the women will spin and there are weavers, has been proved and the cloth fetches high enough prices if of good

quality, to make the profits much greater. But it is useless embarking on this unless one has taken account of this first.

Eri silk is in demand for several reasons and the demand is so ill met that there are imitations on the market made of waste mulberry and of mercerised cotton. But the demand must be understood. We have not exhaustively investigated this point but we have had experience of disposing of cloth. In Calcutta, as in Madras, and some centres in North India, good closely-woven cream cloth is wanted for suits. In Surat, a cheap open woven cloth is sold for dhoties, wrappers, etc., and is worn by Jains and others indoors only. In Assam, a greater range of cloth is made and sold; there is probably scope for enterprise in special fabrics for the Indian and Anglo-Indian trade provided the qualities and special features of eri silk are taken into account. The material is, for instance, admirably suited to all fabrics requiring durability: the "khaki shirting" is probably the ideal material for shikar clothing, expeditions, etc.; the possibilities of eri silk hosiery are not yet tested; the special qualities of the cloths, made of millspun eri, have not been exploited, and it is only in the last year that this material has been made at all in India.

We believe that there is an immense field for guaranteed eri fabrics in India, and that the very special qualities of millspun eri will lead to an immense demand both in India and in Europe; but in every point, enterprise is required. We cannot here adequately discuss this: we have tried to make as great a range of fabrics as possible from eri, and to anyone who is enterprising enough to come to Pusa and see, we will gladly give all the information in our power. Our object here is to point out that one cannot rush blindly into such an industry without forethought, and that while eri silk growing is easy and profitable where the conditions are right, we do not recommend it as an universal profitable industry.

We are here unable to fully discuss the one point that distinguishes eri silk from all others, *i.e.*, that the fact that in no process is life taken and on that account the silk is not objected to by Jains

and others who will not wear mulberry silk, as in getting this latter the cocoons must be stifled. We are told that it is for this reason that eri silk is worn in certain ceremonies and it is probable that some part of the demand is due to this point alone. In that case it is necessary to exactly meet the demand by putting on the market the special fabric required for these purposes and also by retaining the characteristic features of eri silk cloth, so that there can be no doubt of it. The Assam traders have already got a bad name, as their goods are sometimes made partly of mercerised cotton and it will be fatal to any industry if this adulteration is practised. Indian silk fabrics are already largely discredited in India owing to the immense amount of mercerised cotton, rhea and artificial silk, etc., used in their preparation and it is a very great pity that this practice has become so general. It will be a very strong point in the eri silk industry in new places if every article is made only of pure eri silk and is guaranteed so to be. It is a comparatively simple matter to detect admixture of cotton but even without that, the bad qualities of the fabric in actual wear will soon discredit it. We would urge intending-producers to investigate the local trade, find what eri silk is required for, get samples and work to samples, guaranteeing every piece as pure eri and if necessary submitting it to test.

Given that the climate is suitable, that there is castor available, how does one set about starting eri silk? In the first place, one wants a small central rearing house to start and to show people; we have arrangements now for seed-supply as shown above and seed is readily obtained. One wants a few trays as models or one must use cloth or matting. The first brood being through, the moths yield seed which is available for distribution. The cocoons left are cleaned when dry and put by. As rearers produce cocoons from the distributed seed, they are bought and preferably paid for on the basis of clean cocoons, *i.e.*, one cleans the cocoons on the Coryton Machine and pays on the basis of the weight of clean cocoons, or one cleans a sample and pays for the raw cocoons on the sample. If one buys raw cocoons, one may be paying for dead moths, etc., in the cocoons and so lose heavily. Cleaning is essential and the trade

prefer clean cocoons as do the spinners. As the cocoons accumulate, they are packed tightly in 20-seer lots, as much compression being applied as is practicable; we pack in gunny, making each parcel up to 20 seers, as this is the most economical package for goods transit. Some railways give concessions for cocoons, taking them at half rates by passenger train and this concession will doubtless be extended if required. The cocoons are then sent off and the producer is charged one per cent. brokerage by the Calcutta buyers.

If it is intended to spin, it is best to give out the spinning and not to attempt it by spinning in a factory with paid labour. This is an important point, and one of the chief benefits of the industry is that it provides light work for women in their own houses. We give out clean boiled cocoons and expect to get back all the weight, *i.e.*, if we give a seer we expect so much thread, so much waste and if uncleaned cocoons are given, so much refuse; we then pay Rs. 3 to Rs. 5 per seer of thread according to its fineness. The rates, of course, will vary according to locality. The thread is examined and is sorted into qualities, some being finer, some coarser. It is then given to the weaver for weaving with orders as to the class of cloth. The important thing is to get the cloth woven with a proper reed, usually 20 to 22 dents to the inch for suitings, but varying according to the class of cloth. This point must be attended to or unsaleable coarse cloths will be made. The cloths are then taken in, weighed after washing and the weight checked allowing a little for waste. The ordinary sizes of cloth are 11 yards by 27 inches, 7 yards by 40 inches, $3\frac{1}{2}$ yards by 54 inches, but where long warps are made, it is best to warp out to 70 yards and weave 36 to 40 inches wide. For specially good cloths, fine threads are used for the warp but they are doubled to form a very smooth thread; the usual method of doubling is to double it by means of the *charka* or hand-wheel, but this is far more expensive than doubling many pairs of threads at once on a proper doubling machine.

We have already pointed out that no use has as yet been made of eri yarn spun in mills. We have used yarns of the following

counts, made in Bombay :—140/2, 160/2 and 280/2. These yarns are almost identical with mulberry yarns but the unbleached fabric has a peculiar tinge of "dust" colour, a shade like very pale tussur and quite indescribable, while they can be bleached to a good cream colour. The fabrics are very soft and silky, far more durable than mulberry silk and far more resistant to perspiration, dust, etc. But unless bleached, they are not white and this natural colour which does not wash out, must be made use of. It makes the cloths suited specially to chudders, shawls, cloaks, rugs, etc., which are to be worn in the open and which are not required to show dust. The very finest fabrics can be made and the yarns dye readily as ordinary spun silks do. The lower counts of yarn are specially suited for warp, using hand-spun eri in the weft, the resultant fabric in this case being, of course, pure eri and of very good quality.

As things are at present, the mills are dependent upon growers for their supplies, the supplies from Assam being of bad quality very often and not making good yarn on account of the admixture of brown cocoons. It is therefore possible for large producers to send their cocoons to the Bombay Mills and to purchase pure eri yarns at the market rates.

Eri Silk as an Industry in Assam.

No enquiry has been made as to the extent of the present eri silk industry. It is grown for local use in many districts in Assam and in Bogra, Rangpur, Jalpaiguri and Mymensingh in Eastern Bengal. The industry is a small or "home" one, the cultivators rearing in their houses sufficient worms to provide silk for their own spinning and weaving, to clothe themselves with the cloth produced. The surplus is purchased by the factories or by dealers, the former as thread for weaving, the latter for sale in Calcutta for export to Europe, principally to Switzerland.

In Assam, the chief rearing is done from October to February; castor grows best at this time, not growing well during the monsoon

months owing to the excessive rain; the parasitic fly is also troublesome up to October and is not active during the cold weather. For the rest of the year, the worms are kept going in small quantity upon castor or upon its other food-plants, which are said to include ber (*Zizyphus jujuba*), *Jatropha curcas*, keseru (*Heteropanax fragrans*), papaiya (*Carica papaya*), Gulasiphal (*Plumeria alba*), Cassava (*Manihot* sp.), etc. Rearing is done in Assam in much the same way as described above; the trays are usually hung from the roof to keep off ants; the cocoons required for silk are often put in the sun for a few days to kill the contained pupa, though this is not necessary. Both pierced and unpierced cocoons are sold in the bazaar, and those who do not rear their own, purchase them. The cocoons are boiled in ashes and washed; they are then cleaned, by splitting laterally, placed one over another on a stick and spun. About 1¼ seers of cleaned cocoons yield a seer of thread. As much as Rs. 10 per seer is paid for fine thread. The work of spinning and weaving is mainly done by women. Rearing is regarded as successful if 3,500 cocoons are obtained from 5,000 eggs, but usually 2,500 or 50 per cent. only are actually obtained. Ants, parasites, dirty or close rearing and disease lessen the number of worms that mature. Pierced cocoons sell at Rs. 30 to Rs. 60 per maund, unpierced cocoons at half that price.

For a piece of cloth, 3 yards by 54 inches, 1½ seers of thread are required, the weaving costing Rs. 2, six days being required for the weaving, including warping. Handloom factories for the production of the cloth exist at Gauhati, but Muga and Mulberry silks are also woven, as well as silk and cotton. The following are the catalogue prices of pure Eri cloth:

1st class Eri cloth:

A.	3 yards × 1½ yards.	Rs.	20—25.
B.	6—7 yards × 1-1½ ,,	,,	32—40.
1.	,, ,, ,, ,,	,,	26—30.
2.	,, ,, ,, ,,	,,	21—25.
3.	6—6½ ,, ,, ,,	,,	16—20.
4.	5½—6 ,, × 1¼—1½ ,,	,,	14—15.

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TETRIGINÆ (ACRIDIINÆ) IN THE AGRICULTURAL RESEARCH INSTITUTE, PUSA, BIHAR WITH DESCRIPTIONS OF NEW SPECIES

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The members of this subfamily of small acridians are so variable in structure and colouration, that difficulty is experienced in drawing specific distinctions between some of the closely allied forms. A notable instance of this variability is shown in the genus *Euparatettix* Hanc., which in India and Ceylon is represented by a number of species showing considerable fluctuating variations among individuals, as well as apparent hybrids. These various forms, of course, have not been given separate consideration, as only experimental pedigreed breeding can determine the limitations of these forms. The best that could be done was a systematic arrangement of species, and by a careful study of this genus the members can be divided into two groups, as shown in my key to the species, by the characters of the frontal costa and position of the superior paired ocelli.

Walker(1) has described under *Tettix* a number of species of Tettigids from India and Ceylon, some of which I find next to impossible to consign to their systematic position. Kirby has helped matters recently by attempting to place Walker's species in his "Synonymic Catalogue of Orthoptera," but until these species are again clearly described from the types in the British Museum, many of them will remain obscure through one's inability to recognize them from the original descriptions.

(1) Catalog. Dermap. Saltatoria, British Museum, Part V, 1871.

The material forming the basis of this paper was mainly from the Agricultural Research Institute, Pusa, Bihar. The insects were submitted to me for determination by the Officiating Imperial Entomologist, Mr. T. Bainbrigge Fletcher, to whom I tender my acknowledgment. The species are nearly all from India, but some additional species from other regions, represented in my collection, are treated in connection with the foregoing material.

Genus Scelimena.

Serville, Hist. Nat. des Ins. Orthopt., p. 762. 1839; Bolivar, Ann. Soc. Ent. Belg., XXXI, p. 215, 1887; Hancock, Spol. Zeylan. II, p. 107. 1904; Gen. Insect., Fasc. 48, pp. 21–22, 1906.

S. harpago, Serv.

Tetrix (*Scelimena*) *harpago*, Serv. l. c., p. 763, 1839.

This species is represented in the Pusa collection from Matheran, 2,500 ft., April 1908 (*D. Nowrojee*).

Allied to *S. logani* Hanc., but conspicuously differs by the presence of a broad substraight spine on each side arming the lateral lobes of the pronotum. The spines in *logani* Hanc., are hooked and accompanied by a secondary tubercle placed before them on each side.

Genus Criotettix.

Bolivar, Ann. Soc. Ent. Belg. XXXI, p. 222, 1887; Hancock. Spol. Zeylan. II, p. 128, 1904; Gen. Insect. Fasc. 48, p. 27, 1906.

C. extremus sp. nov.

Body large, granose, dark, obscurely mottled with fuscous. Vertex slightly narrower than one of the eyes, little widened backward, the small frontal carinulæ little obliquely elevated laterally and abruptly terminated. Eyes globose; frontal costa narrow, in profile little compressed, arcuate between the antennæ, interrupted just above the paired ocelli, and between the eyes scarcely protuberant yet not distinctly produced; paired ocelli placed between the middle of the eyes; antennæ inserted scarcely lower

than the angles of the eyes. Pronotum deplanate, dorsum granose, uneven between the shoulders, and behind the shoulders distinctly bifossulate, the upper aspect of the base of process presenting a series of uneven depressions and small elevated nodes; median carina discontinuous, irregularly sinuate, obsolete forward near the front border, nodulose between the thoracic sulci, more conspicuous over base of process and obliterated backward toward the pronotal apex; posterior process lengthily acute produced beyond the hind femoral knees; lateral lobes outwardly deflexed and laterally produced in an acute straight spine directed transversely. Elytra elongate, strongly punctate, apices rounded; wings fully explicate, almost reaching the apex of pronotal process. Anterior femora slender, margins entire; middle femora somewhat bilobate below; posterior femoral margins entire or minutely serrulate; posterior tibiæ moderately dilated toward the apices but not like *Scelimena*, the carinæ armed with spines; the first article of the posterior tarsi narrow, equal in length to the third article, the pulvilli rather stout and graded in size from first to the third, the third longest and flat below.

Male type, entire length of body 18·5 mm.; pronotum 17·8 mm.; posterior femora 7 mm.

Habitat: MADRAS, Shevaroys, 4,000 ft. (*C. W. Mason*) Aug. 24, 1907, Pusa collection.

This large species recalls to mind *Scelimena gavialis* Serv., but a closer study of its characters shows its true position in *Criotettix* Bol. and it resembles *C. flavopictus* Bol.

C. montanus sp. nov.

A moderately large species, resembling the preceding; body granose, coloured cinereous. Vertex smoother, slightly narrower than one of the eyes, little ampliate backward, middle carinate; eyes globose; frontal costa lightly arcuate between the antennæ, moderately sulcate and extended above the paired ocelli to the vertex. Antennæ inserted between the lower angles of the eyes. Pronotum deplanate on the dorsum, rather smooth, on each side between

the shoulders provided with very indistinct abbreviated carinula, uneven on the disc, lightly bifossulate behind; prozonal carinæ forward distinct and barely convergent backward; posterior process acuminate produced beyond the hind femoral knees, toward the apex smooth; median carina irregularly undulate; lateral lobes scarcely deflexed, little triangulate produced, but not distinctly spined. Elytra subovate acuminate, the apices rounded, wings reaching to the end of pronotal process. Anterior and middle femora entire; posterior femoral margins above granose or minutely serrulate, the outer face granose; posterior tibiæ somewhat sinuate-curvate, the carinæ armed with spines; the first and third articles of posterior tarsi equal in length, the first to the third pulvilli graded in length, the third longest and more decidedly flattened below.

Male, entire length of body 16·5 mm.; pronot. 15 mm.; posterior femora 7 mm.

Habitat: PUNJAB, Simla, 7,000 ft., Oct. 1907 (*H. M. Lefroy*), Pusa collection.

This species is distinguished from *extremus* by the wider sulcation of the frontal costa, and its extension above or behind the paired ocelli, the smoother dorsum of pronotum, and the triangulate but not spined lateral lobes, which are distinctly spined in *extremus*.

C. grandis sp. nov.

Body slightly larger than *extremus*, rather smooth, resembling that species, while somewhat suggestive of *Eugavialidium* Hanc.; coloured cinereous-rufescent, eyes pale, legs marked with fuscous. Vertex smooth, subequal to one of the eyes, slightly ampliate backward, middle carina very small anteriorly and scarcely projecting; the frontal carinulæ hardly elevated; frontal costa little arcuate between the antennæ, divided above the paired ocelli, moderately divergent forward; antennæ inserted between the lower angles of the eyes. Pronotum slightly angularly excavate at the front margin; dorsum deplanate and somewhat smooth granose,

the disc and base of process longitudinally bifossulate, not bearing nodulate elevations as in *extremus;* posterior process smooth and rounded, lengthily acuminate produced beyond the hind femoral knees; anterior prozonal carinæ convergent backward; very thin abbreviated carinulæ appear between the shoulders; median carina low, strongly depressed, little elevated nodulate between the thoracic sulci forward, straight on process and nearly obliterated toward the apex; lateral lobes decidedly deflexed, the posterior angles bearing distinct triangular sharp spines directed transversely; elytra ovate, narrowed toward the base; wings extended to apex of pronotal process. Anterior and middle femora slender, margins entire, posterior femoral margins minutely serrulate; hind tibiæ sinuate-curvate and armed with spines.

Male and female, entire length of body 17·5—20 mm.; pronotum 17—19 mm.; post. femora 6·4—8 mm.

Habitat: ASSAM, Cherapunji, Khasi Hills. In my collection.

This species resembles *C. flavopictus* Bol., but differs in being larger and more depressed between the shoulders. In my former paper in Trans. Ent. Soc., London, p. 220, 1907, this species was taken for *flavopictus*, but more material in hand for comparison is convincing evidence that they are distinct.

C. tricarinatus, Bol.

Bolivar, Ann. Soc. Ent. Belg. XXXI, p. 224, 1887; Hancock, Spolia Zeylanica II, p. 128, 1904, Figs. 15—15b.

Habitat: MADRAS, Shevaroys, 4,000 ft.; Aug. 24, 1907 (*C. W. Mason*), "on grass," Pusa collection.

Three examples of this species from this locality are indistinguishable from specimens in my collection from Ceylon.

C. æqualis sp. nov.

Body very smooth, granose punctate; coloured pale yellowish brown; eyes globose and prominent. Vertex smooth, narrower than one of the eyes, very little ampliate backward, middle feebly carinate, and depressed on each side, furr-

nulæ arcuate reflexed laterally; frontal costa narrowly divided above the paired ocelli, divergent and more crassate below, in profile arcuate between the antennæ; paired ocelli placed between the middle of the eyes; antennæ inserted between the lower fourth of the eyes. Pronotum subcylindrical forward, the anterior prozonal carinæ nearly obliterated, dorsum deplanate, smooth granose-punctate, lengthily longitudinally bifossulate on disc and base of process, between the shoulders bearing two abbreviated carinæ not at all distinct, posterior process lengthily acute produced; median carina indistinct forward near the anterior border, little elevated between the thoracic sulci and very low obliterated backward toward the apex of process; lateral lobes moderately deflexed, slightly triangulate produced but not strictly spined. Anterior femora slender, margins entire; anterior tarsi annulate with fuscous.

Sex not apparent owing to mutilation; entire length of body to apex of pronotum 18·5 mm.; pronotum 17 mm.

Habitat: Bengal, Phoobsering, Lebong, 5,000 ft. (*Partridge*) Nov. 1910, Pusa collection.

This species recalls *Bolotettix* Hanc. in the smooth dorsum and obliterated prozonal carinæ, but the insertion of the antennæ between the eyes and other characters mentioned above places it in *Criotettix*, Bol.

Genus Loxilobus.

Hancock, Spolia Zeylanica II, p. 134, 1904.

L. assamus Hanc.

Hancock, Trans. Ent. Soc., London, p. 223, 1907.

Habitat: Bengal, Lebong, 5,000 ft., Sept. 1908 (*H. M. Lefroy*), Pusa collection.

In the original description of this species the measurements were inadvertently omitted and are given herewith:—

Male and female, entire length of body 8—9 mm.; pronotum 8 mm.; post. femora 6 mm.

L. hancocki Kirby.

Loxilobus rugosus Hancock, Spol. Zeylanica II, p. 135, 1904; Kirby, Syn. Cat. Orthopt. III, p. 18, 1910, *rugosus* Hanc. preoccupied.

Habitat: BOMBAY, Bassein Fort, Oct. 1909 (*A. Mujtaba*), Pusa collection.

The type from which I described this species is from Ceylon and the examples from Bombay do not differ from the type.

L. acutus Hanc.

Hancock, Spolia Zeylanica II, p. 134, 1904, Figs. 3, and 16*a*, 16*b*.

Male—Body slender, rugose granulate; colour grayish. Vertex slightly wider than one of the eyes, ampliate backward, fossulate on each side between the middle of the eyes, median carina in front joined with the frontal costa formed in a rounded produced profile, viewed in front barely sulcate above the paired ocelli and narrowly divergent forward. Pronotum rugose, bearing small tubercles and granulose lines, dorsum convex between but slightly depressed behind the shoulders; humeral carinæ distinct; prozonal carinæ forward short and convergent backward; median carina interrupted compressed-sinuate; posterior process lengthily acute produced; lateral lobes deflexed, margins oblique, posterior angles armed with small spines with subcarinate base; wings fully explicate, extended beyond the pronotal apex; elytra elongate, apices rounded. Posterior femoral margins entire, external surface rugose; hind tibiæ lightly subsinuate-curvate, armed with spines; first articles of posterior tarsi longer than the third.

Entire length of body 13 mm.; pronotum 12 mm.; post. femora 5 mm.

Habitat: BIHAR, Pusa, July 9, 1910 (*T. Bainbrigge Fletcher*), Pusa coll.

The spines of the lateral lobes in this male are slightly sharper than in the type female from Ceylon, but in other respects it is similar.

Genus Thoradonta.

Hancock, Trans. Ent. Soc., London, p. 407, 1907.

T. spiculoba sp. nov.

Resembling *spinata* Hanc. Body rugose; coloured cinereous, brownish, or fuscous. Vertex about twice the breadth of one of the eyes, subquadrate, in profile scarcely or not produced beyond the eyes; frontal costa narrowly sulcate between the paired ocelli, rather widely divergent forward, in profile sinuate between the eyes and protuberant between the antennæ. Pronotum above rugose, gibbulose forward between the thoracic sulci, ampliate between the shoulders; prozonal carinæ forward nearly parallel; humeral angles distinct and carinate; lateral carinæ behind the shoulders elevated compressed; dorsum between the shoulders bearing two abbreviated carinulæ; median carina strongly sinuate compressed forward on the gibbosity and backward interrupted sinuate; posterior process cuneate, the apex acute and little turned upward passing little beyond the hind femoral knees; posterior angles of lateral lobes dilated but constricted and formed in a produced sharp transverse spine; elytra subovate; wings developed reaching nearly to the pronotal apex and beyond the hind femoral knees. Anterior femoral carinæ sinuate; middle femora below subtrilobate; posterior femora stout, rugose, outer face above bearing a series of nodes; first articles of posterior tarsi little longer than the third, the three pulvilli acute subspinose, nearly equal in length, but the third more flat below.

Male and female, entire length of body 8·7—9·5mm.; pronotum 8—9·5mm.; post. femora 3·7—4mm.

Habitat: Bihar, Pupri, Muzaffarpur (*P. U. N.*); Pusa (*H. M. Lefroy*), Mar. 5, 1904; Durbhanga (*P. U. N.*), Jan. 5, 1905. Pusa coll.

Genus Mazarredia.

Bolivar, Ann. Soc. Ent. Belg. XXXI, p. 236, 1887; Hancock, Gen. Ins. Orthopt. Fasc. 48, p. 42, 1906.

M. latifrons sp. nov.

Dark rufescent. Vertex horizontal, very wide, equal to twice the breadth of one of the eyes, slightly widened backward, frontal carinulæ roundly reflexed laterally, median carina somewhat distinct and roundly protruding at the front border, on each side fossulate; frontal costa produced subsinuate between the eyes and arcuate protuberant between the antennæ, viewed in front moderately sulcate between the paired ocelli and very little widened forward subparallel; paired ocelli placed barely below the middle of the eyes; antennæ placed between the lower angles of the eyes. Pronotum deplanate, rugose, marked with cicatrices backward on the process, forward compressed gibbose between the thoracic sulci, elevated higher than the dorsum, summit little crenulate; prozonal carinæ forward distinct and convergent backward; lateral carinæ extended forward on the shoulders as granulate lines, making them bicarinate; dorsum between the shoulders rather narrow, bearing abbreviated carinulæ on each side, and depressed backward behind the anterior gibbosity; posterior process acuminate produced beyond the hind femoral knees, the lateral carinæ little compressed; posterior angles of the lateral lobes reflexed, angulate, obliquely truncate behind; elytra strongly punctate, rather small, oblong and subobliquely truncate behind; wings explicate reaching to the pronotal apex. Anterior and middle femora little compressed, margins granulate; hind femora elongate, with distinct antegenicular spine, outer face bearing oblique ridges and above provided with a series of large tubercles, the carinæ minutely serrulate-granose, hind tibiæ subsinuous, strongly armed with spines, all the pulvilli of the posterior tarsi equal in length.

Female, entire length of body 14mm.; pronotum 13mm.; post. femora 7·5mm.

Habitat: Bengal, Phoobsering, Lebong, Darjiling, 5,000 ft. (*Partridge*). Pusa coll.

This species nearest resembles *M. lativertex* Brunn., but the pronotum is more gibbose, and differs in the shape of the lateral lobes.

M. chinensis sp. nov.

Similar to the preceding; body moderately crassate; dorsum gibbose forward and strongly rugose-cicatrose; colour dark brownish rufescent. Vertex very wide, fully twice the breadth of one of the eyes, fossulate on each side forward, median carina little roundly produced beyond the eyes; frontal costa sinuate between the eyes and protuberant between the antennæ. Pronotum gibbose forward between the thoracic sulci, the summit crenulate and elevated distinctly higher than the dorsum; median carina distinctly excavate between the humeral angles, backwards irregularly tuberculate or crenulate; dorsum strongly bifossulate longitudinally on the disc and base of process and strongly rugose cicatrose, posteriorly lengthily acuminate produced beyond the hind femoral knees, about four millimetres; elytra of moderate size, the apices obliquely rounded-truncate; wings reaching to the pronotal apex; posterior angles of the lateral lobes of pronotum distinctly angulate deflexed, obliquely truncate subsinuate behind. Anterior femora little compressed; middle femora slender, the carinæ sinuous; posterior femoral carinæ above entire, minutely serrulate, triangularly acute dentate before the knee, inferior carina provided with a series of small light tubercles, the external pagina above bearing a series of large rugose tubercles, the middle portion having oblique rugulæ.

Male and female, entire length of body 17—18mm.; pronotum 16—17mm.; posterior femora 7—8mm.

Habitat: TONKIN, Than Moi, 2—3,000 ft. April—May. (*H. Rolle*). In my collection.

The vertex in this species resembles *latifrons* nov. sp., and *lativertex* Brunn., but it differs in being a larger species, the pronotum above more uneven, rugose; the forward gibbosity more pronounced, and the lateral lobes more strongly deflexed, while the pronotal process is longer, and a series of very small tubercles marks the course of the lower hind femoral carinæ. It differs from *sculpta* Bol. in the more strongly deflexed lateral lobes, and distinctly rugose pronotum, as well as the wider vertex.

M. dubia sp. nov.

Body less crassate, dorsum smoother, though somewhat rugose and not at all gibbose; colour gray, pale variegated or brownish rufescent. Vertex little wider than one of the eyes, deplanate and ampliate backward, front border advanced nearly as far as the eyes, the small frontal carinulæ obliquely curvate laterally, median carina little roundly produced; frontal costa distinctly arcuate protuberant between the antennæ and between the eyes slightly sinuate, moderately sulcate; paired ocelli placed between the middle of the eyes; antennæ inserted in advance of the eyes but scarcely below their lower angles. Pronotum above deplanate, dorsum granulose-tuberculose, between the shoulders transversely convex, bearing two abbreviated carinæ; humeral angles bicarinate; median carina slightly sinuate forward, barely elevated between the thoracic sulci, then straight backward; prozonal carinæ forward distinct and decidedly convergent backward; posterior process lengthily subulate produced, over four millimetres beyond the hind femoral knees; posterior angles of the lateral lobes little deflexed, angle obtuse, obliquely truncate behind; elytra rather large, elongate, apex subrounded truncate; wings extended as far as the pronotal apex. Femora slender, anterior femoral carinæ substraight; middle femoral carinæ subundulate; posterior femora externally rugose, bearing a series of large tubercles above, and oblique rugæ at the middle portion, carinæ above and below entire; the three pulvilli of the posterior tarsi equal in length.

Male and female, entire length of body 15·5—16·5mm.; pronotum 14·5—16mm.; post. femora 6·5—7mm.

Habitat: BENGAL, Phoobsering, Lebong, Darjiling, 5,000 ft. (*H. M. Lefroy*). Pusa coll.

This species has the dorsum more equal than *sculpta* Bol., and lacks the forward gibbosity on the pronotum.

Genus SPADOTETTIX.

Hancock, Spolia Zeylanica, VI, p. 146, 1910.

Body rugose or granose, apterous or winged. Vertex subhorizontal, wider than one of the eyes and strongly produced, middle carinate, very prominently projecting from the front border; viewed in profile acute angulate produced; face strongly oblique; frontal costa sinuate between the eyes; antennæ short, articles elongate, composed of fourteen articles, inserted between the lower angles of the eyes; superior paired ocelli placed between the middle of the eyes and conspicuous in profile view; eyes moderately small, conoidal in profile. Pronotum rugose, or granose, truncate anteriorly; dorsum deplanate, posterior process acute produced; posterior angles of the lateral lobes deflexed truncate or acute produced; anterior and middle femora elongate, slightly compressed, carinæ subundulate or below sublobate; posterior tibiæ scarcely ampliate towards the apices, more or less sinuate-curvate, carinæ armed with spines; first article of the posterior tarsi equal to the third or scarcely longer.

The above generic description is somewhat modified in order to admit the new species from India herewith described. The species *fletcheri* Hanc. from Ceylon is apterous, the new species being winged. This genus belongs in the section *Metrodoræ* near *Mitritettix* Hanc. (*Mitraria* Bol. preoccupied. *)

S. provertex sp. nov.

Body rugose, colour brownish rufescent; eyes small, conoidal in profile; face strongly oblique. Vertex strongly produced, about twice the breadth of one of the eyes, front border carinate, subrounded, the median carina distinctly produced as a projecting tooth and crassate at the apex; in profile acute angulate produced about three-fourths the length of one of the eyes; frontal costa sinuate between the eyes, little compressed between the antennæ; paired ocelli conspicuous; antennæ inserted between the lower part of the eyes; apical articles of palpi widely dilate. Pronotum above deplanate, convex between the shoulders, dorsum rugose bearing distinct elevated lines, tubercles and granules; shoulders

* See Gen. Insect. Fasc. 48, p. 51, 1906; Trans. Ent. Soc., Lond., p. 229, 1907.

bicarinate, humeral angles inconspicuous and carinæ indistinct; prozonal carinæ rather long, parallel but interrupted backward; lateral carinæ on the process distinct, little compressed, and percurrent forward on the shoulders; median carina interrupted tuberculate; posterior process acuminate produced much beyond the hind femoral knees, toward the apex rather stout; posterior angles of the lateral lobes deflexed laminate, constricted subspinate produced and above subcarinate; elytra elongate, apices rounded; wings extended nearly to the pronotal apex. Anterior and middle femoral carinæ below indistinctly bilobate; posterior femur elongate, margins minutely serrulate; posterior tibiæ sinuate-curvate, carinæ armed with spines; the first article of the posterior tarsi having the first two pulvilli equal in length, the third little longer and flattened below.

Female, entire length of body 14·8mm.; pronotum 13·4mm.; post. femora 6mm.

Habitat: MADRAS, Shevaroys, 4,000 ft., Aug. 1907, (*C. W. Mason*). Pusa coll.

This interesting species is much more rugose and larger than *fletcheri* Hanc., and very distinct, though similar in the head characters.

Genus SYSTOLEDERUS.

Bolivar, Ann. Soc. Ent. Belg. XXXI, p. 234, 1887; Hancock, Spol. Zeyl. II, pp. 136, 137, 1904; Gen. Ins. Orth., Fasc. 48, 33, 1906.

S. lobatus sp. nov.

Body little rugose, granulose, eyes strongly exserted, colour grayish fuscous. Vertex narrowed forward, about half the breadth of one of the eyes, frontal carinulæ very small, obliquely curvate laterally, median carina little prominently advanced, about as far as the eyes; frontal costa compressed carinate between the eyes, indistinctly sulcate between the paired ocelli and widely sulcate forward, marked with minute pale spots, in profile arcuate pro-

tuberant between the antennæ and sinuate at the base; antennæ inserted much below the eyes; ocelli placed between the lower fourth of the eyes. Pronotum deplanate, granulose, little rugose in front of the shoulders, lightly constricted; anterior margin not reflexed, sulci strongly impressed; dorsum between the shoulders depressed and behind the shoulders bifossulate; lateral carinæ at base of process distinctly extended forward between the shoulders, making the humeral angles bicarinate; prozonal carinæ forward distinct and subdivergent backward; median carina irregularly undulate; process long acute produced, the apex not at all bispinose; posterior angles of the lateral lobes decidedly deflexed, scarcely sinuate-truncate obliquely behind; elytra small, acuminate toward the apices; wings extended to the pronotal apex. Anterior and middle femora elongate, margins entire; subgenital plate below the female ovipositor dentate produced at the middle.

Female, entire length of body 13·5mm.; pronotum 12·5mm.

Habitat: BENGAL, Phoobsering, Lebong, Darjiling, 5,000 ft. (*Partridge*) October. Pusa collection.

This species has the vertex wider than usual, and it resembles *anomalus* Hanc. These two species recall *Bolotettix*, and seem to merge into that genus.

Genus COPTOTETTIX.

Bolivar, Ann. Soc. Ent. Belg. XXXI, p. 287, 1887; Hancock, Spol. Zeyl. II, p. 152, 1904; Gen. Ins. Fasc. 48, Orthopt., p. 65, 1906.

C. indicus sp. nov.

Obscure grayish brown, process lighter; body minutely rugose-granulate. Head not at all exserted; vertex equal in width to one of the eyes, narrowed forward and fossulate on each side, the supraocular lobes distinct, median carina joined with the frontal costa roundly produced in profile, base entire, the carinæ of frontal costa viewed in front narrowly sulcate behind the paired ocelli and extended subparallel forward; antennæ inserted distinctly between the eyes. Pronotum above minutely rugulose, granose,

and subtuberculose on the process; dorsum between the shoulders convex, and bearing two abbreviated carinulæ; humeral angles widely obtuse carinate; lateral carinæ indistinctly percurrent on the shoulders, base of process slightly depressed; median carina scarcely elevated between the sulcus forward, then sinuous backward; process lengthily acuminate produced beyond the hind femoral knees (two and one half millimetres); posterior angles of the lateral lobes slightly reflexed, the apex narrowly angulate truncate; elytra moderately large, elongate, apices obliquely rounded; wings extended beyond the pronotal apex; anterior femora filiform; middle femora in the male ampliate-compressed; posterior femora distinctly widened toward the base, stout; the third pulvillus of the posterior tarsus distinctly longer than the second; posterior tibial carinæ minutely serrulate and armed with spines.

Male, entire length of body 12mm.; pronotum 11·5mm.; post. femora 5·3mm.

Habitat: BOMBAY, Kalyan, 14 Aug. 1910 (*T. Bainbrigge Fletcher*). Pusa coll. "At light."

This species is smoother than *fossulatus* Bol. from Ceylon, the pronotum less tectiform, has longer wings and larger elytra.

C. parvulus sp. nov.

Body very small, coloured brownish, lighter and variegated with fuscous on the pronotum. Head not at all exserted; vertex narrowed forward, little narrower than one of the eyes, and fossulate on each side, frontal carinulæ subtransverse but angularly reflexed laterally, middle carinate; frontal costa arcuate produced between the antennæ, barely subsinuate between the eyes, and little sinuate at the base, viewed in front widely and evenly divergent forward; antennæ inserted between the lower part of the eyes, articles strongly elongate. Pronotum anteriorly scarcely obtuse angulate, posteriorly abbreviated, the apex widely rounded, and reaching to about the middle of the hind femora; dorsum granulate, transversely tectiform between the shoulders and subbifossulate behind the disc; median carina compressed, little arcuate

forward, straight on the disc, sloping toward the apex; humeral angles obtuse carinate; posterior angles of the lateral lobes obtuse, little reflexed, the superior sinus very shallow; elytra very minute, elongate; wings not visible. Anterior femoral margins below little compressed entire; middle femora in male wider compressed, the width about one half that of the length, bicarinate above, margins entire; posterior femora strongly crassate, the superior carinæ minutely serrulate and bearing an angulate lobe before the knees, carina below marked with black spots; the first and second pulvilli of the posterior tarsi acute spinose, the third longer.

Male, entire length of body to apices of hind femora 7mm.; pronotum 4mm.; hind femora 3·5mm.

Habitat: BIHAR, Chapra, (*Mackenzie*). Pusa collection.

C. curtipennis sp. nov.

Body robust, short-winged, above minutely rugose-granose, colour entirely ochre-brown except two dark spots behind the disc. Vertex narrowed forward, subequal in width to one of the eyes, transversely carinate, angularly reflexed at the sides, little arcuately elevated, fossulate on each side between the forward half of the eyes, the front advanced as far as the eyes; frontal costa widely sulcate, in profile convex between the antennæ, not at all sinuate between the eyes; paired ocelli placed between the lower third of the eyes; antennæ inserted considerably below the eyes. Pronotum deplanate above, gibbulose forward between the sulci; the median carina arcuate forward, depressed between the shoulders and then undulate interrupted backward; dorsum rather wide between the shoulders, rugose granulose, and somewhat tuberculose, prozonal carinæ forward distinct, very short, and convergent backward; pronotal process produced cuneate, reaching to the apices of the hind femora; posterior angles widely rounded, little reflexed; elytra of moderate size, acuminate towards the apices; wings extended little beyond the pronotal apex. Anterior and middle femoral margins subentire, below setose or hirsute; posterior femora crassate, the superior carina at the distal half

serrulate and tridentate including the apical spine, external lateral carina subtuberculose, inferior carina sparingly setose; hind tibiæ crassate and armed with strong spines; first article of the posterior tarsi longer than the third, the first and second pulvilli small, the third as long as the first and second combined.

Female, entire length of body 9·7mm.; pronotum 9mm.; post. femora 6mm.

Habitat: BENGAL, Lebong, Darjiling, 5,000 ft. June 1909, (*H. M. Lefroy*). Pusa coll.

The position of the paired ocelli and the insertion of the antennæ in this species is like the structure found in *Mazarredia* Bol., and the present species occupies a place on the border line between the two genera.

Genus HEDOTETTIX.

Bolivar, Ann. Soc. Ent. Belg. XXXI, p. 283, 1887; Hancock, Spol. Zeyl. II, p. 148, 1904; Gen. Ins. Fasc. 48, Orthopt., p. 60, 1906.

H. gracilis de Haan.

Acridium (*Tetrix*) *gracile* de Haan, Bijdrag. Orthopt., p. 169, 1843; Bolivar, l. c. p. 286; Hancock, Spol. Zeyl. II, pp. 149, 150, figs. 19-19*b*, 1904.

Habitat, BIHAR, Pusa, Chapra. Pusa collection.

Some of these specimens resemble representatives in my collection from Java and Ceylon, but there is also a variety that is more slender between the shoulders.

H. costatus sp. nov.

Body granulose, colour variable, often pale ferruginous or fuscous, or pale testaceous on the dorsum. Vertex narrowed forward, equal in width to one of the eyes, angulate produced, middle carinate; frontal costa narrowly sulcate, viewed in profile strongly arcuate produced beyond the eyes; the vertex joined with the frontal costa obtuse angulate, face oblique; paired ocelli placed between the upper fourth of the eyes; antennæ inserted between

the lower fourth of the eyes. Pronotum above granulose, front obtuse angulate, posterior process lengthily subulate extended beyond the hind femoral knees; median carina compressed forming a low graceful arc, highest on the disc and sloping backward; dorsum between the shoulders tectiform, bearing two obscure abbreviated lines on the disc, and just behind the humeral angles bicarinate; prozonal carinæ subdivergent backward; posterior angles of the lateral lobes narrowed subacute; elytra rather large subacuminate and narrowly rounded toward the apices; wings extended much beyond the pronotal apex. Anterior femora smooth, elongate, entire; middle femora little compressed in female, in the male strongly incrassate, the upper margin arcuate; the first and second pulvilli of the posterior tarsi acute spinose, the third hardly longer or subequal with the second and little flattened below.

Male and female, entire length of body 12·5—14·5mm.; pronotum 10—11·5mm.; posterior femora 5mm.

Habitat: BIHAR, Chapra; Pusa: BENGAL, Naraingunj; Dacca. Pusa coll.

Taken "On grass," "At light" and on "River bank."

A number of examples in the Pusa collection taken by Mr. Fletcher and others.

This species is at once distinguished from *gracilis* de Haan by the obtuse angulate profile of the head, the low arcuate median carina of the pronotum, and the narrowly sulcate frontal costa.

There is a variety from Durbhanga that has a slightly smaller stature, but not ranking as a distinct species.

H. diminutus sp. nov.

Resembling *gracilis* Haan, especially in the arcuate median carina of the pronotum and vertex, but differs in the smaller stature, scarcely angulate anterior border of pronotum and minutely rugose granulate dorsum. Vertex subequal in width to one of the eyes; frontal costa roundly produced, viewed in front rather widely sulcate. Pronotum anteriorly scarcely obtuse angulate, backward

acuminately produced beyond the hind femoral knees; elytra moderately large, apices little narrowed rounded; wings fully explicate, extended much beyond the pronotal apex. Middle femora of male little compressed but not inflated, margins above and below substraight, and minutely granose; posterior femora externally scabrous-granose; the first pulvilli of the posterior tarsi small acute, the second little longer and acute, the third as long as the first and second united and flat below.

Male and female, entire length of body 10—12mm.; pronotum 8—9mm.; posterior femora 4·8—5mm.

Habitat: BOMBAY, Surat. Pusa collection.

Genus TETRIX.

Latr., Hist. Nat. Crust. Ins. III, p. 284, 1802; Hancock, Gen. Ins. Fasc. 48, Orthopt., p. 57, 1906, etc.; *Acrydium* Geoffr., Hist. Ins. I, p. 390, 1762, etc.; *Tettix* of authors.

T. variegatus Bol.

Paratettix variegatus Bol., Ann. Soc. Ent. Belg. XXXI, p. 280, 1887; *Tettix atypicalis* Hanc., Spol. Zeyl. II, p. 142, 1904.

Habitat: S. INDIA, Pondichery: Ceylon.

This species has the pronotum tectiform, and the median carina arcuate forward. In my former article on the "Tettigidæ of Ceylon" (Spolia Zeylonica II, p. 142, 1904) under the genus *Tettix* I described this species under the name *atypicalis* Hanc., and the short-winged form as *ceylonicus* Hanc., the former being figured. My name *ceylonicus* Hanc., can be retained for the short-winged form of Ceylon, the name *atypicalis* falling as a synonym. Whether this is one of the species described earlier by Walker is impossible to determine from his descriptions.

Genus PARATETTIX.

Bolivar, Ann. Soc. Ent. Belg. XXXI, p. 270, 1887; Hancock, Spol. Zeyl. II, p. 144, 1904; Gen. Insect. Fasc. 48, Orthopt., p. 55, 1906.

P. indicus Bol.

Ann. Soc. Ent. Belg., p. 281, 1887.

Habitat: BIHAR, Chapra; Gorakhpur, June 20, 1910; Pupri, Muzaffarpur (*T. V. R. Aiyer*). Pusa collection. Oriental India (Bolivar).

This long-winged species somewhat resembles *Tetrix subulatus* L., and it presents a variety of coloration similar to that species.

Genus EUPARATETTIX.

Hancock, Spol. Zeyl. II, p. 145, 1904; Gen. Ins. Orthopt. Fasc. 48, p. 55, 1906.

Members of this genus are represented by a considerable number of species in India and Ceylon. They differ from typical species of *Paratettix* Bol. in the exserted eyes, the pronotum in front not touching them, and the first and third articles of the posterior tarsi being about equal in length. They are all provided with fully developed wings.

Key to species of India and Ceylon.

1 (2). Pronotal disc bearing abbreviated carinæ on each side, *variabilis* Bol.

2 (1). Pronotal disc not bearing abbreviated carinæ.

3 (10). Frontal costa arcuate produced, in profile showing above the paired ocelli, base entire; paired ocelli placed between the middle of the eyes; rather long species.

4 (9). Head and eyes distinctly exserted, face oblique.

5 (7). Median carina of pronotum low, entire or nearly so.

6 (8). Hind tibiæ brownish or pale dusky not marked with black; pronotum long subulate, narrow between the shoulders; head exserted; middle femora elongate, margins entire, *tenuis* sp. nov.

7 (5). Median carina of pronotum more or less undulate.

8 (6). Hind tibiæ margined with black; head exserted, *personatus* Bol.

9 (4). Head and eyes very little exserted, eyes nearly on level with dorsum; pronotum moderately crassate, smooth granulate; median carina scarcely undulate, little elevated substraight over disc; colour grayish, hind tibiæ pale, *corpulentus* sp. nov.

10 (3). Frontal costa not produced, arcuate protruding between the antennæ but in profile obscured by the eyes, not showing above the paired ocelli; paired ocelli placed distinctly below the middle of the eyes; shorter species.

11 (12). Pronotum distinctly rugose tuberculose, bearing small nodules; median carina strongly sinuate and subnodulose backward behind the disc on hind process, the lateral carinæ of process bearing distinct projecting crenulations; hind femora distinctly tuberculate on outer face. *nodulosus* sp. nov.

12 (11). Pronotum little rugose tuberculate; median carina compressed-undulate or sinuate; hind femora bearing very minute projecting tubercles on external pagina; hind process with the lateral margins not at all or indistinctly crenulate, *parvus* Hanc.

13 (14). Head and eyes little exserted, face oblique; median carina of pronotum more or less undulate; colour of body variable, hind tibiæ pale, or with dusky marking darker toward the apices; middle femora of male strongly crassate; body nearly smooth or little rugose, *crassipes* sp. nov.

14 (13). Head not at all or scarcely exserted, face nearly vertical; pronotum almost touching the eyes; median carina lightly multisinuate; body minutely rugose; colour brownish-rufescent; hind tibiæ and tarsi rufescent, infuscate toward the apices, *bengalensis* sp. nov.

E. tenuis sp. nov.

Colour variable, often grayish, reddish, or dark fuscous variegated, dorsum plain or rarely with black spots; wings strongly caudate. Head and eyes exserted, vertex narrower than one of the eyes, front carinate and interrupted at the middle, truncate, little roundly elevated and reflexed at the sides; frontal costa arcuate produced beyond the eyes, viewed in front moderately

sulcate, extended above the paired ocelli; antennæ very slender, articles elongate, inserted between the lower angles of the eyes; paired ocelli placed between the middle of the eyes. Pronotum slender, anteriorly truncate, subtectiform between the shoulders, lengthily acuminate produced beyond the hind femoral knees, nearly as far as the apices of the hind femora; anterior prozonal carinæ very short and parallel; median carina nearly straight, compressed percurrent, entire, often very slightly arcuate or substraight on the disc, then substraight or concave backward; posterior angles of the lateral lobes turned down, acute angulate and apex obtuse; elytra subovate, apices rounded; wings strongly extended backward, reaching beyond the apices of the hind tibiæ; first and second femora slender, in the male little wider and compressed, but distinctly elongate, carinæ entire; posterior femora slender; first and second pulvilli of hind tarsi minute, acute dentate, the third longer than the second, the first and third articles of posterior tarsi equal in length.

Male and female, entire length of body 15—17mm.; pronotum 11·5-13·5mm.; posterior femora 5mm.; wings passing pronotum 3—3·6mm.

Habitat: Bihar, Pusa; Chapra: Bengal, Lebong; Dacca: United Provinces, Partabgarh.

Numerous examples of this very long-winged species in the Pusa collection.

This species belongs near *personatus* Bol.

E. personatus Bol.

Bolivar, Ann. Soc. Ent. Belg. XXXI, p. 278, 1887; Hancock, Spol. Zeyl. II, p. 146, 1904, fig. 10-10*b*.

Habitat: Bihar, Pusa: Bengal, Dacca. Four examples in the Pusa coll.

These specimens from India differ slightly from specimens in my collection from Ceylon, the median carina of the pronotum being more sinuate on the disc; the wings fuscous or pale spotted.

E. corpulentus sp. nov.

Body smooth, granulate, colour grayish or reddish, variable, tibiæ pale often cinereous, rarely obscure infuscate. Head very slightly or not at all exserted. Vertex narrower than one of the eyes, front carinate, reflexed at the sides, middle carinate; frontal costa arcuate produced, barely sinuate at the base. Pronotum somewhat crassate, posteriorly subulate, lengthily passing the hind femoral knees; dorsum smooth or very slightly rugose, lightly constricted forward; median carina percurrent, entire or very little crassate or elevated between the thoracic sulci forward, obliterated near the front border, and elevated substraight on the disc; posterior angles of the lateral lobes turned down, acute angulate, the apex narrowly rounded; wings lengthily extended beyond the pronotal apex. Anterior and middle femora elongate, carinæ entire; first and second pulvilli of posterior tarsi acute spinose, the third longer than the second and substraight below.

Male and female, entire length of body 13—17·5mm.; pronotum 10—13mm.; post. femora 5—6mm.

Habitat: Bihar, Chapra; Pusa; Bengal, Dacca: Assam. Pusa collection. This species also occurs in Ceylon.

E. crassipes sp. nov.

Colour ferruginous, or dark, rarely with light longitudinal fascia above, and black spots behind the disc. Body pilose below. Head exserted, moderately obliquely placed. Vertex narrower than one of the eyes, little narrowed forward; frontal costa lightly arcuate produced between the antennæ, but not at all produced above the paired ocelli when viewed in profile, lightly sinuate at the base; paired ocelli placed between the lower third of the eyes. Pronotum posteriorly subulate, extended much beyond the hind femoral knees; dorsum plain or little rugose, convex between the shoulders; median carina little compressed, lightly undulate, little elevated crassate forward between the thoracic sulci; posterior angles of lateral lobes acute angulate, apex rounded or narrowly obtuse; elytra oblong, apices rounded; wings extended beyond

the pronotal apex. Anterior femora narrow, margins entire; middle femora in female little wider and compressed, in the male strongly crassate; posterior femora little rugose on the outer pagina, with a series of crassate tubercles above, and bearing oblique tubercles but not distinctly projecting; all three pulvilli of the posterior tarsi acute spinose, the third little longer than the second; posterior tibiæ pale, often indistinctly clouded and darker toward the apices.

Male and female, entire length of body 11—12·5mm.; pronotum 8·5—9·5mm.; posterior femora 4—4·5mm.

Habitat: BIHAR, Pusa; Chapra; Pupri, Muzaffarpur: BENGAL, Dacca. Pusa collection.

This species is subject to great variation, some specimens being more brownish on the pronotum and with the hind tibiæ suffused with brown. One specimen even being black excepting the hind tibiæ. This variation applies also to the median carina of the pronotum which often presents undulations, and indistinct abbreviated lines between the shoulders, which are more often absent.

E. bengalensis sp. nov.

Brownish ferruginous, hind tibiæ brownish or suffused with fuscous darker toward the apices; body hirsute below. Head not at all exserted, placed slightly oblique, pronotum nearly touching the eyes. Vertex little narrower than one of the eyes, narrowed forward; frontal costa arcuate between the antennæ but not at all produced above the paired ocelli, base very slightly sinuate. Pronotum subulate; little crassate and convex between the shoulders; dorsum minutely rugose, rarely with indistinct lines between the shoulders, median carina thin, percurrent, but multiundulate; hind process extended beyond the hind femoral knees; posterior angles of the lateral lobes acute angulate, with the inferior margins oblique, toward the apex narrowly curved and truncate, barely reflexed; elytra elongate, rather narrowly rounded at the apices; wings extended beyond the pronotal apex. Anterior femora elongate, margins entire, middle femora in the females elongate, margins

subundulate, but in the male strongly crassate, larger toward the basal half; hind femora moderately crassate, with projecting tubercles on the outer face, and a series of large tubercles above; all three pulvilli of posterior tarsi acute spinose, the third nearly the same size as the second.

Male and female, entire length of body 9·5—10·5mm.; pronotum 8—8·5mm.; hind femora 3mm.

Habitat: BIHAR, Pusa; Pupri, Muzaffarpur: BENGAL, Dacca. Pusa collection.

E. nodulosus sp. nov.

Brownish ferruginous or gray, hind tibiæ brownish darker toward the apices, or in variety with two bands of black. Head little exserted, summit of eyes nearly on level with median carina of pronotum. Vertex narrower than one of the eyes; frontal costa arcuate between the antennæ but not at all produced above the paired ocelli. Pronotum subulate, extended backward beyond the hind femoral knees; dorsum rugose, minutely nodulose, widened between the shoulders; humeral angles carinate; prozonal carinæ forward small and indistinct; pronotum decidedly constricted between the sulci; median carina strongly sinuate, little compressed elevated, and subundulate on the disc, but backward strongly sinuate-nodulose; dorsum nodulose laterally above the base of the hind femora; lateral margins towards the apex of process provided with several pairs of projecting tubercles or crenulations, the apex barely crassate-truncate; posterior angles of the lateral lobes having the apices rather narrowly rounded; elytra elongate, apices rounded; wings extended beyond the pronotal apex. Anterior femora narrow, rugose-pilose; middle femora in the female little compressed, margins distinctly undulate-lobate and pilose, in the male distinctly crassate, sublobate at the middle; posterior femora externally strongly tuberculate, bearing distinct projecting tubercles, superior carinæ minutely serrulate before the knees; all three pulvilli of the posterior tarsi acute spinose, the third nearly equal to the second.

Male and female, entire length of body 8·5—10·5mm.; pronotum 7·5—8mm.; posterior femora 3·5—4mm.

Habitat: BIHAR, Pupri, Muzaffarpur; Pusa: BENGAL, Dacca. Pusa collection.

This species resembles *parvus* Hanc., but differs in the strongly sinuate-nodulose median carina of the pronotum, and the brownish hind tarsi. In *parvus* Hanc. the tarsi are marked with white and black bands, and the pronotum is less rugose.

E. parvus Hanc.

Hancock, Spol. Zeyl. II, 145, 1904, *Euparatettix pilosus* Hanc., Trans. Ent. Soc., London, p. 410, 1909.

Habitat: BIHAR, Chapra: Pusa: ASSAM.

A study of the series of specimens in the Pusa collection convinces me that this species is synonymous with *E. pilosus* Han.

Genus SAUSSURELLA.

Bolivar, Ann. Soc. Ent. Belg. XXXI, p. 303, 1887; Hancock, Gen. Ins. Orthopt. Fasc. 48, p. 72, 1906.

Key to species including those from India.

1 (4). Wings not passing the pronotal apex.

2 (3). Inferior margin of pronotal cornu concave; length of pronotum 14mm. (Java) *cornuta*, Haan.

3 (2). Inferior margin of pronotal cornu straight, and shortly produced, median carina of pronotum nearly horizontal throughout; length of pronotum of male 11mm. (Burma), *brunneri* Hanc.*

4 (1). Wings passing the pronotal apex.

5 (10). Pronotal cornu straight.

6 (9). Direction of cornu strongly ascendant, oblique.

7 (8). Cornu lengthily produced, in female 4mm., margin below straight; pronotum of female 21mm., *sumatrensis* Bol.

* The species called *Saussurella cornuta* de Haan, described and figured by Brunner as occurring in Burma, is evidently a distinct species. I have applied the name *Saussurella brunneri* to this new species, and thus characterize it in the key.

8 (7). Cornu moderately produced, in female 2·5-3mm., margin below barely convex; pronotum of female 19mm.; middle lobe of subgenital plate subangulate; in male transversely truncate not widened apically. (Sumatra), *cornifrons* Hanc.

9 (6). Direction of cornu very slightly oblique; pronotum of female 20mm.; middle lobe of subgenital plate convex. (Borneo), *borneensis* Hanc.

10 (5). Pronotal cornu more or less decurved toward the apex.

11 (16). Apex of cornu very slightly decurved.

12 (13). Body moderately large; pronotum of male 16·5mm.; sides of pronotum distinctly compressed behind the disc; subgenital plate of male widely transversely excised, widened apically (India), *curticornu* Hanc.

1 (12). Body smaller, less than 16mm.

14 (15). Colour above fuscous-virescent; pronotum of female 14·5mm. (Java), *javanica* Bol.

* Body fawn coloured; length 14·5mm. (China), *cucullifera* Walk.

15 (14). Colour above yellowish brown, cornu strongly ascendant; female pronotum 15·5mm.; middle lobe of subgenital plate acute produced; subgenital plate of male emarginate. (India), *indica* Hanc.

16 (11). Apex of cornu distinctly decurved; pronotum of male 12·5mm. (Burma), *decurva* Brunn.

S. indica sp. nov.

Body conspersed with coarse rounded granulations; colour yellowish brown, legs somewhat infuscate. Vertex very wide; frontal costa viewed in front more widely sulcate just above the insertion of the antennæ, the rami slightly convergent forward, median facial carina at the vertex rather distinct; antennæ brownish, slender, and inserted between the lower part of the eyes, the four or five apical segments black; palpi pale. Pronotum anteriorly

* *Tettix cucullifera* Walk.

produced in a stout, compressed, ascendant process slightly decurved which in profile forms nearly an acute angle with a line drawn forward from the dorsum, the process near the base little wider in diameter than one of the eyes, the superior margin between the eyes and the apex strongly arcuate, below oblique but towards the apical half slightly concave ; at the basal sides arcuately excavate for the reception of the eyes : viewed from above the process cuneate, the median carina acute compressed towards the apex, lateral margins barely concave or substraight, and apex rounded; dorsum triangularly depressed-fossulate on each side behind the shoulders : median carina between the shoulders concavely depressed and backward convex on base of process and barely concave towards the apex, the median and lateral carinæ obsolete towards the pronotal apex ; posterior process extended beyond the hind femoral knees and slightly turned up at the apex ; lateral lobes deflexed obliquely nearly rectangulate, posterior inferior sinus very widely obtuse : elytra small, elongate, apex rounded, outer face black, distinctly circumbordered with pale brownish-ochre ; wings extended beyond the pronotal apex from ·5mm.—1mm. Middle femora armed with apical spine ; posterior tibiæ sinuate-curvate, carinæ bearing moderately distinct spines, particularly on the outer border ; the three pulvilli of the posterior tarsi equal in length and obtuse. Subgenital plate of male emarginate, in the female trilobate, the middle lobe below the ovipositor acute produced.

Male and female pronotum including cornu 13—15·5mm. ; hind femora 6—7mm. ; frontal cornu 2·6—3mm.

Habitat : Bengal, Lebong, Darjiling, 5,000ft. June 1909 (*H. M. Lefroy*). Pusa collection.

S. curticornu sp. nov.

Colour dark brown, infuscate forward on the pronotum, sides and legs, dark brown below. Furcation of frontal costa widened above the antennæ, median facial carina at the vertex obsolete ; antennæ pale, the six apical articles black. Pronotum anteriorly produced in a stout compressed cornu, obliquely ascendant, very

lightly decurved, and not quite so elevated or so long produced as in *indica*, viewed in profile the superior margin rounded just behind the apex, below straight, but the extreme apex very indistinctly decurved, viewed from above acuminate, sides straight, the apex rounded; dorsum longitudinally canaliculate on each side of the median carina, median carina backward compressed at the base of process and becoming thinner toward the apex; lateral carinæ percurrent on the shoulders and incrassate; lateral lobes deflexed obliquely, strongly produced, acute, the apex hebetate; inferior sinus very wide obtuse angulate; pronotal process backward lengthily produced, horizontal, extended beyond the hind femoral knees; elytra elongate, apex rounded, externally black and circumbordered with dark brown; wings extended beyond the pronotal apex 7mm. subgenital plate of male widely transversely excised, widened apically.

Male, length of pronotum 16·5mm.; frontal cornu 2·3mm.

Habitat: BIHAR, Pusa, Oct. 1906 (*C. S. Misra*). Pusa coll.

S. cornifrons sp. nov.

Colour fuscous, face and lateral lobes behind, pale ochreous, legs marked with ochreous or in the male often entirely that colour excepting the wings and elytra, or infuscate on the dorsum. Rami of facial costa subparallel, median carina above near the vertex barely evident. Antennæ pale ochreous, the apical five articles black; palpi nearly white. Pronotum anteriorly produced in a straight oblique process, viewed in profile the superior margin straight but at the apex rounded, the margin below barely convex, the apex not at all decurved or sinuate, apical half narrowed toward the apex; in cross section at the middle triangular; viewed from above acuminate, the apex narrowly rounded, sides straight, distinctly carinate basally over the eyes; dorsum subtriangularly fossulate behind the shoulders, median carina compressed, nearly horizontal backward from the frontal cornu, or indistinctly sinuous; posterior process lengthily extended beyond the hind femoral knees; lateral lobes obliquely deflexed, acute angulate produced;

inferior sinus barely indicated and very widely obtuse; elytra subovate, or elongate, the outer face black circumbordered with fuscous, the apices often marked with white, distinct in females; wings extended beyond the pronotal apex from 1—1·5mm. Subgenital plate of male transversely truncate, but not widened apically; subgenital plate in the female trilobate, the middle lobe below the ovipositor subangulate. Male and female pronotum including cornu 17·5—19mm.; posterior femora 7—8·3mm.; pronotal cornu 2·5—3mm.

Habitat: SUMATRA, Soekaranda (*Dohrn*). My collection.

S. borneensis sp. nov.

Rather large, colour fuscous, face, and pronotal lobes behind pale, hind femora mottled with light ochreous, palpi pale tinged with fuscous. Carinæ of frontal costa parallel, rather pronounced, median facial carina above distinct, as well as the frontal carina of vertex next to the eyes. Pronotal cornu straight in profile, its direction only slightly oblique, strongly produced beyond the head, margin above straight but rounded at the apex, below substraight, viewed from above strongly narrowed forward, acute compressed, apex rounded, sides indistinctly concave; prozonal carinæ forward on the dorsum indistinctly indicated; median carina of pronotum compressed, nearly horizontal from the thoracic sulci forward to the hind apex; dorsum longitudinally fossulate behind the disc on each side; posterior process lengthily produced beyond the hind femoral knees; lateral lobes acute angulate, distinctly produced; inferior sinus very widely obtuse angulate; elytra subovate, apices rounded, impressed with black, surrounded with pale elevated line below becoming crassate apically and lighter; wings extended beyond the pronotal apex nearly one millimetre. Subgenital plate below the female ovipositor trilobate, the middle lobe convex.

Female, length of pronotum 20mm.; posterior femora 7·5mm.; cornu 3mm.

Habitat: BORNEO, Lawas, Sept. 1909. Sarawak Museum.

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September 1912 ENTOMOLOGICAL SERIES Vol. IV, No. 3.

MEMOIRS OF THE DEPARTMENT OF AGRICULTURE IN INDIA

THE BIG BROWN CRICKET

(*BRACHYTRYPES ACHATINUS*, STOLL.)

BY

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AGRICULTURAL RESEARCH INSTITUTE, PUSA

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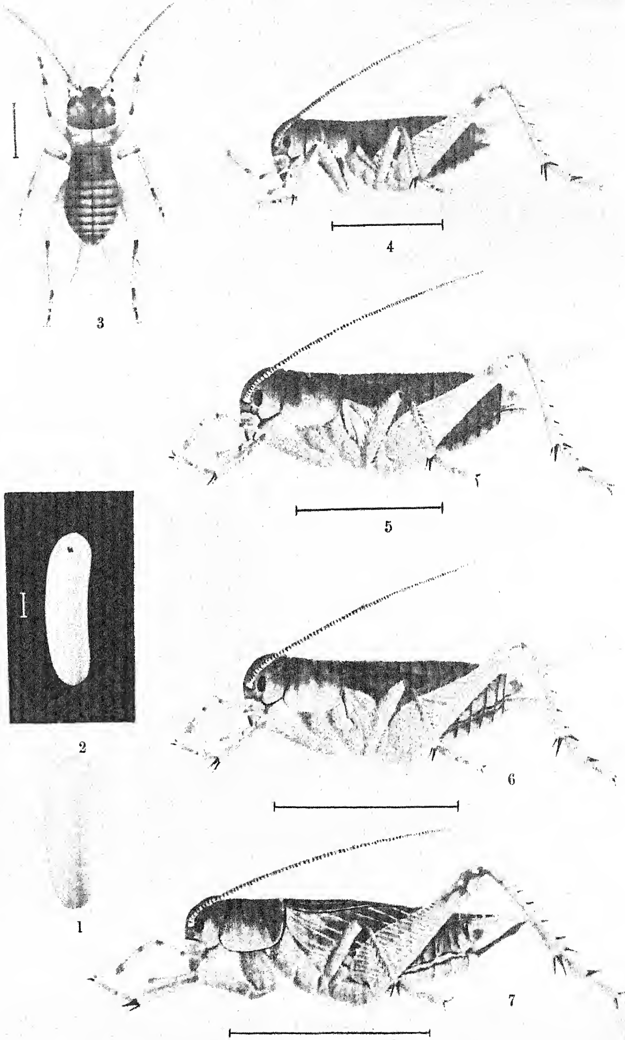
PLATE X.



THE BIG BROWN CRICKET.
(*Brachytrypes' achatinus*, Stoll.)

EXPLANATION OF PLATE X.

THE BIG BROWN CRICKET.

(*Brachytrypes achatinus*, Stoll.)

Fig. 1. Egg when laid.
,, 2. Egg before hatching.
,, 3 Young nymph, dorsal view.
,, 4. Nymph in the third stage, side view.
,, 5. ,, ,, ,, fourth ,, ,, ,,
,, 6. ,, ,, ,, fifth ,, ,, ,,
,, 7. The adult cricket, side view.

(The hairlines indicate the actual sizes of the stages).

THE BIG BROWN CRICKET.

BY

C. C. GHOSH, B.A.,

Assistant to the Imperial Entomologist.

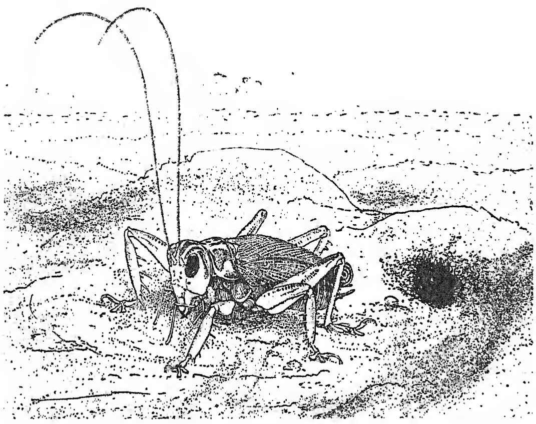
The large brown cricket (Plate X) (*Brachytrypes achatinus*, Stoll.) belongs to the family Gryllidæ of the saltatorial (jumping) group of the Order Orthoptera. It is a large insect measuring about 1¾ inches from head to tail and is about ½ inch thick across the thorax and the abdominal region. The antennæ are thread-like and about as long as the body. The colour is brown. The inner parts of the forewings, or tegmina, lie flat on the back, their outer parts being bent at right angles down the sides. The hind wings are like thick membranes and remain folded longitudinally and hidden under the forewings, which overlap each other on the back. In the majority of cases the left tegmen is above the right one, but the reverse arrangement is also found in both the sexes. The hind legs are much bigger than the first two pairs and are suited for jumping, their femora being very thick and broad and the tibiæ spiny on the posterior side. On the hind end of the body there is a pair of cerci more than ½ inch long. The head is deflexed so that the mouthparts are turned downwards. The mouthparts are conspicuously developed, the mandibles being very large and powerful. The eyes are black and prominent. The females possess a long ovipositor pointing posteriorly and upwards. There is a pair of tympana on each fore-tibia near its junction with the femur.

OCCURRENCE AND DAMAGE.

These crickets are probably widely distributed throughout India. They work at night; therefore their presence is not

always detected, and the damage they cause is in most cases attributed to wrong sources. They have been noted in Comilla (Jute and Rice); Sikkim; Assam (Tea); Sibsagar; Jorhat; Khasi Hills; Murshidabad; Calcutta; Sadeya; Isubu; Mongomalobah; Solanah; Pusa; Bankura; Patna; Champaran (Indigo); Bogra; Dacca and Rungpur. In June 1893 they were reported as damaging jute and rice in Comilla. In July of the same year much damage caused by them to teaplants in nurseries was reported from Jorhat. They cut the young plants off level with the ground at night. They were reported making burrows from 9 to 18 inches deep in the ground specially in sandy soils and concealing themselves during the daytime; they sat at the mouth of the hole in the evening and could be recognised by their shrill piping. (Indian Museum Notes, Vol. III, No. 5, pp. 77-78). In 1903, the Deputy Director of Forests, Myitkyina, Burma, reported damage caused by these crickets in gardens and nurseries. In April 1906 the Collector of Bogra reported damage to jute which he said had commenced from about the 3rd week of March; the insects appeared there every year, but usually disappeared as soon as the rains set in. In April 1907, the Collector of Dacca reported similar damage to jute and rice which had commenced early in March. In April 1910, Babu Baidya Nath Tarafdar of Pubna in reporting the occurrence of these crickets said: "These insects are causing serious damage to young jute plants; whole fields have been destroyed and seeds have been resown two or three times in some cases, but still without success. When the plants grow to a height of about 9 inches they are more or less immune. The insects are numerous and live underground in burrows which they dig in the fields. They come out at night and cut down the plants, eating some and dragging some into their underground nests.........They are not so common in lands having enough moisture in the subsoil and are found in large numbers in those having hardly any moisture to the depth of about 9 inches below the surface. They also occur in loamy soils. All these lands are usually flooded in the rains."

In April 1911, it was reported from Jelhara Indigo Concern in Champaran that the cultivation of indigo was being ravaged by an army of *bherwas.* The destruction they caused was described as appalling. They totally destroyed plants 6 inches to 9 inches high. At this time indigo was the only green food available to them and therefore the damage was very great. In one village out of 45 acres of indigo worth about Rs. 40 to Rs. 50 per acre, 25 acres was utterly destroyed. The same habit of nocturnal feeding was reported here as well. On later enquiry



BHERWA.—(SCHIZODACTYLUS MONSTRUOSUS).
(From Indian Insect Life).

it was ascertained that the damage was caused by the large brown crickets and not by *bherwas.* What are known as *bherwas* in Behar are quite different insects as will appear from the figure. They are greyish yellow and not red brown. The wings of *bherwas* are peculiarly coiled at the end and the tarsi of their legs are peculiar. They are bigger and more weird looking insects than the large brown crickets. They also live in underground burrows like these crickets, but they are found principally in sandy beds of rivers and are not so common, though

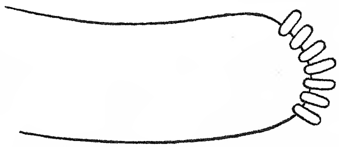
not altogether rare, in cultivated fields or high lands. They have not been observed to feed on a vegetable diet and therefore to damage any plants in the way the large brown crickets do. In confinement also they have not fed on leaves, etc., but have greedily fed on caterpillars and frogs. Most probably they are predaceous on other insects, etc. Therefore it appears that the reports in Indian Museum Notes, Vol. II, No. 6, p. 172, and Vol. III, No. 4, p. 46, about *bherwas* cutting tobacco, indigo and other crop plants, are based on mistaken observations. The damage is attributable to the large brown crickets. It is however possible that the *bherwas* may damage plants by tunnelling through the soil and cutting through roots which obstruct their passage; but any such damage seems to be accidental rather than normal.

LIFE HISTORY.

The big brown cricket (*Brachytrypes achatinus*, Stoll.) passes through only one cycle in the course of the year. Eggs are laid in burrows under the ground about the month of September just after the rains have ceased. They hatch in about a month. The habits of the crickets are well described in the reports of occurrence noted above. Throughout their life they live in burrows which they dig in the ground. They are nocturnal in habit and come out of their underground burrows only at night when they feed or collect food which they carry into the burrows. They possess very powerful cutting jaws with which they shear through the stems of almost all kinds of young plants which are then carried off. In this way they sometimes cause incalculable damage to young crops. The young crickets are similar to the adults in appearance; only they are small and possess no wings. They grow, moulting at intervals and developing small wings in the later stages as will be evident from the figures of different stages in the plate. They become adult when the wings are fully developed. Some grow more quickly than others and attain the fully winged adult stage about April. The majority become adult by June; while yet a few may be found in the

nymphal stage as late as August. In spite of the early development mating and egg-laying do not take place until the proper season in September—October. The adult crickets die after laying eggs ; occasionally one may survive till late in winter ; thus, for example, one adult female was found on 4th December at Rungpur among myriads of young nymphs. In winter the crickets are young, but by March they are sufficiently large to cause serious damage to newly started crops. Hence almost all the reports noticed above are found to have been made about the month of April. Then, as will be seen later on, the first heavy shower of rain brings about, directly or indirectly,* the death of many, while the surviving ones have to leave the flooded or submerged places and therefore also the crops standing in those places.

Egg.—Each egg is about 4-6½ m.m. in length, the eggs laid in the same cluster being variable as to length and about 1½ m.m. in diameter. The egg is cylindrical in shape with rounded ends. It is a little curved on one side, the back of the enclosed embryo lying against the concave side. The surface is smooth and without ornamentation ; the colour is yellow, turning creamy white later on (Figs. 1 and 2, Pl. X), the two eyes of the embryo being clearly seen as dark spots in the advanced state. Eggs removed from the soil and kept exposed to the atmosphere turned greyish in colour ; before hatching also they turn greyish ; (Fig. 2, Pl. X). At this time if looked at carefully the segments of the body of the embryo are discernible. The eggshells are thin, membranous and soft. The



A diagrammatic illustration to show how the eggs are laid at the end of the burrow.

* Rain is destructive to the crickets by flooding their tunnels and driving them out into the open where they are eagerly preyed on by almost every one of the larger birds which is normally or occasionally insectivorous. Crows, Shrikes, the Blue Jay, the Hoopoe, the King Crow, Cuckoos, Owls, Hawks and Kingfishers may be mentioned in particular, and the irrigation of a field about April usually attracts enormous numbers of these birds to devour the crickets which are then perforce compelled to desert the security of their subterranean burrows.—T. B. F.

eggs are laid in a cluster at the end of the burrow underground. For the purpose of depositing eggs the hole is always made to end in hard soil. Each egg is thrust separately into the soil, so that the eggs do not touch one another. In the Insectary two clusters were found at a depth of about 2 feet and one at a depth of about 1 foot. In a single hole only one cluster of eggs was found. Of the three clusters found in the cage in the Insectary :—

(1) One contained 38 eggs.

(2) The second one contained 37 just hatched young ones and one unhatched egg.

(3) The third one contained 34 eggs, but there were probably more as a few eggs of this cluster were destroyed while being dug out.

Several adult females were kept confined separately in glass troughs filled with earth ; the troughs were emptied at intervals and the earth examined for eggs. One female laid 47 eggs between 10th and 15th September. Probably on account of frequent disturbance these eggs were not deposited all in the same fashion as shown in the diagrammatic illustration. Some were found thrust into the earth, while others were lying loose in the burrow among loose earth.

It seems that the small number of eggs found in the burrows in the Insectary does not represent the possible number which may be laid by a female. In the second week of August several females captured at random were dissected and each of the two egg masses, one on each side of the abdomen, seemed to contain about 40 to 45 eggs. At this time the eggs were small, the biggest measuring about 3·5 m.m. ; all were cylindrical and elongate oval in shape and provided with a cylindrical tapering tail. The colour was whitish. In the second week of September several females similarly captured at random were again dissected. The egg masses were now much bigger, on account of the development of the eggs, many of which were of the same shape, size and colour as those actually deposited in the soil. These developed eggs were seen to have

lost the tail. In the same cluster there were many other eggs which were not yet completely developed and had the tail; they were in different stages of growth and were, therefore, of different sizes. It thus seems that the female does not deposit all the eggs in the same cluster and at the same time; if after the first oviposition she lives and the immature eggs have time to develop, she can deposit eggs again. The egg masses at this time were found to contain many more eggs than in August. The following are the numbers found in 4 females :—

(1)	Right	cluster	103	of which	54	seemed	mature.
	Left	,,	97	,,	49	,,	,,
(2)	Right	,,	89	,,	41	,,	,,
	Left	,,	95	,,	40	,,	,,
(3)	Right	,,	110	,,	63	,,	,,
	Left	,,	102	,,	52	,,	,,
(4)	Right	,,	106	,,	76	,,	,,
	Left	,,	102	,,	81	,,	,,

Further observations about oviposition and other facts connected with the hatching of eggs in the natural condition could not be made. In the case of the eggs removed from the burrow the young ones hatched by bursting the shell at the head end; either the end was opened like a cap on the head and the shell burst longitudinally to some extent on one side from the opening thus made, or there was only one fissure longitudinally which extended for some distance down the side. In most cases the delicate inner skin (oölemma) stuck to the empty shell as a small crumpled mass by means of a thin thread; in a few cases it stuck to the emerging young nymph and was thrown off separately. The eggs laid between 10th and 15th September began to hatch on the 16th of the following October and continued to hatch till the 25th October.

Stages.—In all the stages of growth the crickets retain a remarkable similarity of appearance, general shape and also of colour. Males and females are distinguishable from the early stages, as in the females the ovipositor is present in these stages and grows with the growth of the insect.

As the nymphs live in burrows underground it has not been possible to observe their moults accurately. Several were kept in glass dishes filled with earth and a watch kept on them. They, however, did not get on so well and only one survived to attain the adult stage. It cast five skins in all, as was evident from the changes of appearance. The approximate dates are given below. The habit of eating the cast skins rendered the observation of moults still more difficult.

The young one hatched out in the cage—10th October.

First moult	19th November.
Second ,, ...	27th January.
Third ,, ...	21st March.
Fourth ,, ...	7th May.
Fifth ,, ...	15th June.

At the fifth moult it attained the adult stage. It was a male.

1*st Stage.*—Young nymph—(Fig. 3, Pl. X).

Young nymphs vary in size in the same manner as the eggs do. A newly hatched young nymph measured about 4½ m.m. from head to hind end and about 1½ m.m. across head and abdomen. The antenna was about as long as the body.

A young nymph about four days old measured as follows :

Length from head to hind end—8 m.m.

Breadth across head, prothorax and middle of abdomen—about 2½ m.m.

The anterior part of abdomen is narrower.

Antennæ, about 8 m.m. long, thread-like and thick at the base and gradually tapering towards the end, made up of numerous small joints and covered with very minute hairs.

There is a pair of cerci—about 3 m.m. long—at the hind end of the abdomen pointing posteriorly.

The general colour is light brown, the abdomen being paler and showing a dark tinge in the middle. In general appearance and shape the young nymph resembles the adults, only it is small and possesses no wings.

The pronotum is big. The segments of the body are clearly distinguishable.

2nd Stage.—

Length from head to hind end	... 14	m.m.
Breadth across head and anterior part of prothorax	... 5	m.m.
Breadth across abdomen	... 4 5	m.m.
Antennæ about	... 15	m.m.
Cerci about	... 4·5	m.m.

There is hardly any change in appearance and colour except that the abdomen is slightly darker.

3rd Stage.—(Fig. 4, Pl. X).

Length from head to hind end	... 24	m.m.
Breadth across head and anterior part of prothorax	... 8	m.m.
Breadth across abdomen	... 7·5	m.m.
Antennæ	... 25	m m
Cerci	... 8	m m.

In general appearance and colour the nymph has hardly undergone any change.

Laterally the mesonotum and metanotum show a small elongation which is really the beginning of the formation of the wingpads.

4th Stage.—(Fig. 5, Pl. X).

Length from head to hind end	... 29	m m.
Breadth across head and anterior part of prothorax	... 9	m.m.
,, ,, abdomen	... 8·5	m.m.
Antennæ	... 30	m.m.
Cerci	... 9	m.m.
Mesothoracic winglobes	... 3	m.m,
Metathoracic ,, ...	... 4 5	m.m.

The winglobes lie lengthwise and flat on the body. There is hardly any other change.

5th Stage.—(Fig. 6, Pl. X).

Length from head to hind end	... 33	m.m.
Breadth across head and anterior part of prothorax;	... 9·5	m m.
,, ,, abdomen	... 9	m.m.
Antennæ	... 32	m.m.
Cerci	... 9·5	m.m.
Lobe of tegmina	... 6	m.m.
Lobe of hind wings	... 9	m.m.

The tegmina only touch each other over the back. All the lobes lie flat and lengthwise along the body.

6th Stage.—(Fig. 7, Pl. X).

When reared in confinement the size of insects varies a great deal and is usually smaller than is the case when they live and feed freely. But the size of the brown crickets is seen to vary a great deal even when they live in the open free condition. The following are the measurements in m.m. of a few adults reared in the Insectary :—

From head to hind end.	Across the prothorax.
♀—30	11
♂—31	11
♂—36	12
♀—39	13

The following are the measurements in m.m. of some adults captured in the fields :—

♀—26	9
♀—27	9
♂—32	11
♂—37	12
♂—37·5	12·5
♂—38	13
♀—38	12
♂—39	1·25
♂—39	13
♂—40	13
♀—42	13
♂—42	13
♀—46	13

In the same way the nymphs in all the stages vary a great deal in size.

The measurements of other parts of the last female captured in the field are the following :—

Antennæ	44 m.m.
Across middle of abdomen	14 m.m.
Cerci	14·5 m.m.
Ovipositor	9·5 m.m.

The measurements of the parts vary according to the size. A general description of the adult insect has been given in the beginning. The modification of the tegmina of the males for the production of sound has been noticed under the heading "song." The adult crickets have never been observed on the wing and their wings are very small for their bulk. They take long jumps, their hind legs being very well developed.

FOOD.

The big brown crickets seem to be omnivorous. They can feed and live on the leaves and sometimes the fruit of almost any kind of plant. They have been fed in the Insectary with the shoots and leaves of the following, *viz.*, ground-nut, mangold wurzel, tobacco, lucerne, sannhemp, castor, sunflower, brinjal, arum, bottlegourd and cucumber. They were given and ate pieces of bread and a bait prepared with fine wheat chaff, molasses and water. They have been reported to damage rice, indigo, tea and jute and various garden plants. What they eat can be very easily found out by digging open their burrows into which they are in the habit of carrying their food. The following were found in some burrows dug out in the Insectary compound (leaves, etc., found in the same burrow are noted separately; the plants were available in the compound and the leaves, etc., were more or less eaten) :—

(1) Dry *sissoo* leaves partly eaten, green *dubh* grass *(Panicum dactylon).*

(2) *Mutha* grass *(Cyperas rotundus Linn).* Loranthus leaves, about half eaten. Mango leaf, dry and partly eaten. Raw *ghurmi* fruit (cucurbitaceous) more than half eaten.

(3) Castor leaf.
Mango leaf, dry.
Shoot of *Dodonea viscosa.*

(4) Cotton leaf, dry.
Sissoo leaf, dry.

(5) Bottlegourd leaf, dry.

(6) Brinjal leaf, dry.
Sweet potato leaf.
(7) *Gular* leaf, dry.
Cucumber shoot.
(8) Young sunflower shoot.
(9) Young marigold shoot.
(10) Young shoot of *Celosia cristata.*
(11) Mulberry leaf.

Note :—I have also found stones of litchi fruit in their burrows.—T. B. F.

Feeding.—The crickets do not seem to climb upon any plants but cut and carry away what they can get at on the ground. Among the things found in their burrows were fallen and also dry leaves which they found lying on the ground. Young plants they cut just above the ground and either eat them on the spot or carry them into their burrows. When the plants grow tall they become safe. Thus it will be seen from the reports quoted above that when jute and indigo plants grow more than 9 inches high they are practically immune from attack. In the Insectary compound, brinjal, sunflower and cabbage seedlings which had been transplanted were found to have disappeared the next morning.

The following are some of the records of the feeding habits of these crickets as observed in the Insectary :

10th March.—Nymphs collected and put in the cage. Every afternoon shoots of lucerne were placed on the surface of the earth. The crickets came up at night and ate them and also dragged some shoots into their burrows. Small fragments of bitten leaves were found lying on the surface, so that evidently they had fed at night above the soil. Shoots almost entirely or partly eaten were found in the burrows on opening them up. The crickets probably feed at leisure in the burrows during the daytime.

Mangold wurzel, ground-nut, sannhemp and castor leaves were also eaten. Castor leaves appeared to be greatly appreciated. Sunflower leaves were also eaten, but castor leaves seemed

to be preferred to sunflower and were sometimes liked more than lucerne.

3rd June.—Sannhemp preferred to lucerne.

7th June.—Castor preferred to lucerne.

15th June.—Lucerne preferred to castor.

31st July.—All the crickets were fully winged and adult. The whole cage was dug out, but no eggs or young ones found.

On 27th August.—Eight shoots of lucerne and four pieces of bread were supplied to the crickets. On the next morning two shoots of lucerne and five pieces of bread were found missing, either eaten or taken under the earth.

30th August.—Cage searched; no eggs found.

31st August.—The crickets were supplied with ten shoots of lucerne and four balls of bait (each about 1 inch in diameter). The bait was prepared by mixing molasses, a little water, and the fine chaff obtained by passing coarse *ata* (wheat flour) through a fine sieve. No poison was added.

On the next morning two shoots of lucerne and one ball of bait had completely disappeared; two other balls were found half-eaten.

On 2nd September.—Eight shoots of lucerne and two balls of bait were supplied. On the next morning none of the shoots had been touched, but a little of one ball of bait had been eaten.

The same food was left in the cage, and on the following morning four out of the eight shoots had disappeared whilst the bait had not been touched any more.

On 5th September.—8 shoots of lucerne,
2 castor leaves,
2 balls of bait were supplied. On the next morning it was found that nothing except portions of the bait had been touched. The same food was left in the cage, and on the following morning the bait and one shoot of lucerne had disappeared.

On 8th September.—The crickets were given eight shoots of lucerne and two balls of bait, but on the next morning only a portion of one ball of bait had been eaten.

The same food was left in the cage, and on the following morning two shoots of lucerne and portions of both the balls of bait had been devoured.

20th September.—No eggs were found.

2nd October.—Young ones found in the field.

10th October.—Young ones hatched out in the cage. They were fed principally with shoots of lucerne. Other leaves, *e.g.*, brinjal, arum, and cucurbitaceous leaves were also supplied and they used to feed on them. The first one became adult on 15th June.

BURROWING.

After hatching from the eggs the young crickets live for some time in the burrow of the parent. It is not known how long they live thus, but apparently it is not more than two or three days. After this they disperse and each makes a separate burrow for itself. These burrows can easily be located and the young cricket dug out as it lives within a distance of about 3 to 6 inches from the surface. Small particles of earth are thrown out in a heap over and round the mouth of the burrow, whose entrance is indicated by a slight depression about the middle of the heap. These small heaps of earth are quite characteristic and are extremely common about the latter half of October by which time the eggs hatch. The young crickets, like the grown up ones, come out at night in search of food, and it seems most of them do not find their way back to the old nest and have to hide themselves by making fresh burrows; in fact, all the small heaps of earth seem to be freshly thrown out when one sees them in the morning. Usually only a single young one is found in the same pit, which goes down at an angle and shows no ramifications. Gradually these heaps of earth are observed to diminish in number, evidently indicating a diminution in the number of the crickets themselves. As the crickets grow, the burrows have to be bigger and therefore more earth is thrown out; and they go down deeper and tend to be tortuous and may have ramifications; they never go down straight. Big burrows

also are easily located by the earth thrown up. The adult crickets do not seem to dig a fresh nest every night; in a court-yard a male was noticed in August—September to sing sitting at the mouth of the same burrow, consecutively for 23 days, after which it was captured. Either they are capable of returning to their nests or take shelter in any burrow which they find ready at hand. Probably it is for this reason that sometimes two, three or four crickets, not necessarily of different sexes, are found in the same burrow; but as a rule only a single cricket is found in one burrow. The first heavy shower of rain in April, May or June floods the burrows and drives out the crickets; many are killed by crows and other enemies. They take shelter and hide in odd places, many coming into the houses; this however is only a temporary habit; they soon resume their subterranean existence and after this generally choose places which have not been flooded, places which have already been submerged being apparently considered to be ineligible sites. In the rainy season the crickets are mainly found in places which are directly under the shade of trees, but it cannot be determined what leads them to select such situations. At this time they rarely make fresh burrows but live in old ones, so that no earth is found heaped near the mouth, which is quite open and goes down obliquely. Almost all the burrows are tortuous and may possess several ramifications and occasionally more than one opening. One, two or three crickets may be found in the same burrow at this time of the year; fresh burrows with earth thrown out are not however altogether rare on comparatively high lands.

The process of digging the burrow is actually carried out by the jaws, with which the earth is bitten and loosened and cut into small pellets. The loosened earth is then drawn under the breast and thrown out by the legs. This process is followed until when the earth can no longer be thrown out by the legs as the burrow gets deeper. The loosened earth is then pushed all the length of the burrow and out by means of the front part of the head.

These crickets excavate their tunnel in the ground in order to prepare a nest for themselves. They do not burrow on like the mole crickets; unlike the mole crickets also, they burrow deeper and the greatest depth noticed was about 3 ft., but it is frequently less. When the burrow is tortuous and has many ramifications, it may come up to quite near the surface in any part of its length.

The cricket can be dug out, as its hole is very easily traced: as the hole is dug it retreats and can be caught at the extreme end of its tunnel. Pouring water into the hole brings it out quickly. If a small pit is formed at the mouth of the hole and water remains collected there after the entire pit has been filled, the cricket cannot escape; it comes up and floats on the water as if dead. Evidently water affects it very quickly. When there is a heavy shower and burrows get submerged probably many are drowned and die in this way.*

From the mode of their life it is evident that the crickets cannot live in mud or muddy soils. They require a soil in which they can make a clear hole which they can enter or leave with ease.

SONG.

In loudness, shrillness and intensity of song† the big brown crickets excel all other insects, including the cicadas of the plains. Like that of the cicadas the song is continuous but more powerful and shrill. It is a long continued, high-pitched and uniform *Krirn-rn-rn-rn* of which the *r* is more distinct than the *n*. Very rarely there may be a slight variation in the pitch or the song may be stopped abruptly in the middle and begun again at the same pitch. Occasionally only somewhat prolonged chirpings are heard, but that only from individual crickets and at other times than that of general singing, *e.g.*, late hours

* (Still more are flooded out and fall a prey to birds and other enemies.—T. B. F.).

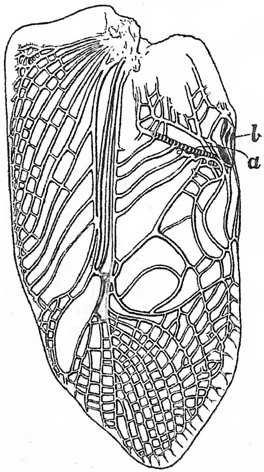
† The term song is rather a misnomer. The noise produced is a continuous high-pitched shrill vibrant whistle which at close quarters positively makes one's ears ring for a considerable time afterwards. I can only like the noise to that of a "devilene" whistle.—T. B. F.

of the night or early hours of the morning. The cicadas in the plains delight in singing when the midday sun shines hot in summer. The crickets rarely sing at this time of the day. They usually begin when the day draws to a close and continue till a late hour in the night. Some may not sing early in the evening, being noticed to begin as late as 11 P.M. The season of their song commences with the close of the rains; when the song of the big brown crickets becomes general it is an unfailing indication of the rains being at an end; this fact has been observed consecutively for four years at Pusa. At this time the song is heard in all kinds of places, not even the courtyards of houses being excepted. All sing during the evening, but individual ones may be found singing in the morning or any time of the day and night. Before the proper season commences an occasional song may be heard from about the month of April, but it is by no means common.

It is the male crickets which sing; the females are not capable of producing any sound and are "voiceless" like "Cicadas' wives."* The wing covers or the tegmina of the males are modified for this purpose. On the under surface of each wing cover, on the portion of it lying on the back, a vein towards the base is raised and provided with a number of small ridges, thus becoming a sort of a file. On the upper surface the position of this vein is marked by a depression across the wing covers. Also a small part of the outer margin of each wing cover is so modified as to present a stiff raised edge, by the margin being bent down at an angle. The sound is produced by the rubbing of the file of one wing cover over the raised edge in the margin of the other; the length of the file is at right angles to the length of the rubbing edge. The sound is capable of being produced by both the tegmina and the provision of the sounding organ in both seems to be due to the irregularity noticeable in their arrangement on the back; usually the left tegmen lies above the right, but

* It was a Greek philosopher who said "Happy the Cicadas who have voiceless wives."—T.B.F.

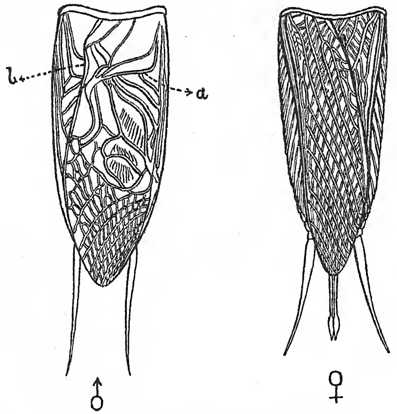
the reverse arrangement is not uncommon. The outer half of each tegmen is bent down the side and the rest lies along the back: therefore each tegmen is comparable to a thin concave metallic pot. When the sound is produced the tegmina are raised from the body and vibrated laterally at an extremely rapid rate, and the wings lie on the back as in the natural condition. As the tegmina are raised the sound is not dulled as it would be if they remained in contact with the solid body.



The under surface of the right tegmen of a male showing (*a*) the file, and (*b*) the modified portion of the edge which rubs the file of the other tegmen.

The cricket comes up from its underground burrow, sits just at the opening with the head turned towards the hole and the body away from it, and then pours forth its song. In the beginning there are usually one or two chirps and then it is one continuous song. The chirpings are produced by convulsive lateral movements of the tegmina in the same way as the song, in which the movements are very rapid and continuous. The song is

stopped at the sound of footsteps or the dropping of a stone and the insect quickly disappears into the burrow. It can, however, be stalked while singing if approached noiselessly. One was thus approached on tiptoe with a lantern in hand at 9 P.M. It was singing loudly and was so much absorbed in the song that it paid no heed to the approaching light which was placed at a distance of about one inch only. The light was carried steadily in such a way that it did not cast shifting shadows of the surrounding balsam and rose plants. The cricket went on singing. The tegmina were raised up from the body, forming an angle of about 60° and the wings were lying on the back. In the middle, the song was stopped for about a quarter of a minute and then commenced again. When the song was stopped the tegmina were still held raised in the same position as when singing. After about five minutes more the song was stopped again when the cricket discovered that there was a light quite near and it at once slipped into the hole, the tegmina being brought down at the same time. The light attracted two large toads, and although



The back of a male and a female.
(*a*) the vein with file; (*b*) the rubbing edge.

they came quite near the cricket, they showed no hostile attitude towards it. Many were similarly approached afterwards, and it was found that the tegmina were held raised up to form an angle of 45° to 60° with the body while singing.

It is said that the males sing in this manner in order to charm and attract the females, and it is significant that the season of their song is the season for mating and egg laying. Soon after this merry nuptial period they die.

The tegmina of the females are smooth compared with those of the males. Leaving aside the long ovipositor which marks the females, the sexes in the adults can be distinguished by looking at the tegmina alone.

ENEMIES.

A small mite is found on the body under and near the base of the wings of the adult crickets which, however, do not seem to be inconvenienced appreciably on this account.

On 5th May a species of Mabuia (a Scincid lizard) was seen attacking a nymph of the 5th or penultimate stage at about 3 P.M.; the cricket was trying to jump away but it was too much maimed and could clear only short distances; the Mabuia was running after it and inflicting bites on the legs and body. It was an unusual hour for the cricket to be out. Most probably it was chased out of its burrow. Ultimately the cricket was dragged into a bamboo bush, and it as well as its assailant could not be traced any longer. It is quite probable that a certain number of the crickets are disposed of in this manner.

The metallic green Digger Wasp, *Sphex lobatus*, is frequently seen to prey upon this cricket. It enters the hole of the cricket and drags it out. The prey is made insensible by a sting and buried in some conveniently near hole or crack in the soil, after which the wasp lays an egg on its body. The phenomenon of a cricket being dragged by the Digger Wasp is common, especially in the dry, hot months before the break of the monsoon. It could not be determined how far the wasp is a check on the increase of the crickets.

When the crickets are driven out of their burrows by the first heavy rain during the day-time, a large number of them are disposed of by crows and numerous other birds. During the night also, owls and other predaceous nocturnal birds and animals, prey on them when they come out of their burrows and roam about in search of food.

But with all these checks the Large Brown Cricket is a field and garden pest of the first magnitude.

PREVENTIVE AND REMEDIAL MEASURES.

The most vulnerable point in the life of the large brown crickets is when the first heavy shower of rain in April, May or June drives them out of their burrows. One year the first heavy shower fell about 10 o'clock in the morning and the Insectary compound became strewn, as it were, with the brown crickets. Two kerosene tins full were collected in the course of about half an hour by four men. A dip in the water made them sluggish and they were not jumping, but were either walking or running. A better method is to beat them with a broom, one effective stroke of which is sufficient to kill them. More can be killed in this way than can be collected in the same space of time. Besides some skill is required to catch them or they bite when caught and may cut through the skin; even when caught with skill by the neck they kick with their hind legs whose spines prick and scratch the skin. They should be attacked as soon as they are driven out because they run about in search of hiding places and soon disappear from view. Crows pick out many, but the majority escape; if it rains heavily, as happened on the occasion referred to above, they are hardly attacked by crows, which are deterred by the rain. The same effect is produced if their nesting place can be artificially flooded. They quickly come out of their burrows and should be beaten to death with brooms; but flooding is not always practicable.

Digging out, or pouring water in every hole is a very tedious and expensive process although the insect can be

destroyed in every case; treatment of the holes individually in any way is impracticable.

From the records of their feeding in the Insectary it seems probable that they can be killed by poisoned baits, which may either be green shoots or leaves dipped in a strong poison, or *bhusa* prepared in the following manner. The baits should be placed here and there near and among the holes.

Bhusa	...	...	... 1 md.
Sambul (white arsenic)	...	...	... 1 seer.
Gur	...	...	... 2 seers.
Water	...	...	... enough to make all these into a paste.

But the baits should be used judiciously in order to produce any effect at all. The best time would be March or a little earlier, before any crop is sown. If there be weeds growing they should be cleared off and so also fallen leaves, even though dry, of any big tree which may be standing near the place. Thus the crickets may not be diverted and all will surely take the bait. Another method would be to spray with a strong poison all the weeds and young and low vegetation. But this will not be as cheap and as effective as when the weeds are cleared off and the limited amount of poisoned food only remains available to the crickets.

In a garden the simplest plan would be to keep watch for fresh burrows, and if noticed early before they go down very deep, the crickets can be driven out with only a little water and without digging. In a courtyard eight crickets were driven out with less than half a kerosene tin of water. The burrow need not be actually flooded. The heaped up earth is pushed aside and water is poured into the hole; the cricket comes near the mouth where its head is visible, but does not leave the hole. Now a *khurpi* is plunged a bit obliquely into the earth either to cut the cricket or intercept it.

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October, 1912. ENTOMOLOGICAL SERIES. Vol. IV, No. 4.

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LIFE-HISTORIES OF INDIAN INSECTS—IV (HYMENOPTERA)

BY

GOBIND RAM DUTT, B.A.

Assistant to the Imperial Entomologist

AGRICULTURAL RESEARCH INSTITUTE, PUSA

PUBLISHED FOR

THE IMPERIAL DEPARTMENT OF AGRICULTURE IN INDIA

BY

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PREFACE.

This Memoir, which has been written by Mr. G. R. Dutt, Assistant in the Entomological Section at Pusa, deals with the life-histories of some of the Hymenoptera found at Pusa and gives short notes on their habits.

The arrangement and nomenclature of the species dealt with are those followed in the volumes on Hymenoptera in the Fauna of British India series.

Illustrations previously used in Indian Insect Life are marked "I. I. L."; those not so marked are original.

PUSA,
18th April 1912.

T. BAINBRIGGE FLETCHER,
Offg. Imperial Entomologist.

MEMOIRS OF THE

ERRATUM.

On page 249 *for* Plate III *read* Plate XIV.

ERRATA.

ENTOMOLOGICAL SERIES. VOL. IV, No 4.

MEMOIRS OF THE DEPARTMENT OF AGRICULTURE IN INDIA.

LIFE HISTORIES OF INDIAN INSECTS—IV (HYMENOPTERA)

On page 192, lines 5 and 6 from top

For narrowly, and the hypopygium two large lateral spots on the 7th segment, yellowish white, etc.

Read narrowly, two large lateral spots on the 7th segment and the hypopygium, yellowish white, etc.

On page 258, line 13 from bottom

For *the word* pupa *read* pupæ.

On page 262, line 6 from top

For margin. On the outer surface, etc.

Read margin, and on the outer surface, etc.

LIFE HISTORIES OF INDIAN INSECTS: (HYMENOPTERA).

BY

GOBIND RAM DUTT, B.A.,

Assistant to the Imperial Entomologist.

FAMILY MUTILLIDÆ.

Mutillids, otherwise known as Velvet-ants, on account of the velvety pubescence on the abdomen of the females, are commonly seen at Pusa from March to October, every year. Males have long graceful wings, generally smoky in colour, but the females are wingless. The former are seen flying about on plants, and the latter running about on the ground like ants, from which they are distinguished by the absence of nodes, between abdomen and thorax, which are so conspicuous in the ants. Whenever a male Mutillid is observed flying close to the ground with wings well spread out, head sometimes drooping, sometimes raised, just skimming over the surface of the soil, now touching it, now receding, it is probably in search of a female wasp. On finding her, it swoops down and carries her off by the neck. Pairing may take place at any convenient locality, on a branch of a tree, or elsewhere. If disturbed, they usually fly away together; it is seldom that they part. The fact that the male shakes the female at intervals, mentioned on p. 187 of Mr. Lefroy's 'Indian Insect Life,' has been observed by me in the case of *Mutilla sexmaculata,* Swed.

Female Mutillids sting badly; the sting is very poignant, but causes no appreciable swelling. I was once stung by *Mutilla durga,* Bingh. ♀ in the palm of my right hand; the pain caused was very severe, but lasted for only 5 or 6 minutes.

Mutillids lead a parasitic life upon other Aculeate Hymenoptera. I bred from the cells of *Sceliphron madraspatanum* (F.) a Mutillid wasp which is identical with *Stenomutilla oglana*, Cam., in all its structural features, but has the basal abdominal segment black, not red.

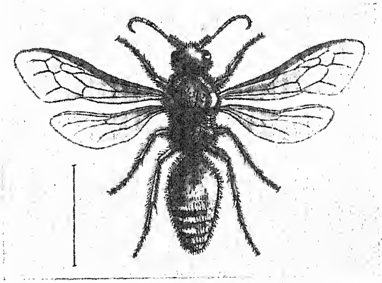


FIG. 1. MUTILLA SEXMACULATA, MALE.
(I. I. L.)

Mutilla poonaensis, Cam. ♀, *Mutilla metallica*, Cam. ♀, and *Mutilla yerburyi*, Cam. ♂, were reared, from broken clay cells which were unmistakably those of Eumenid wasps.

Mutilla regia, Sm. ♂ & ♀ were reared from the cells of *Eumenes conica*, F., and once from below the sandy soil where *Bembex orientalis*, Handl., *Philanthus pulcherrimus*, Sm., and *Palarus* spp. were nesting, I obtained a cocoon from which emerged a very pretty female Mutillid, probably, an undescribed species (Pl. XIV, Fig. 6).

Economic. Excepting the cases quoted above, it is not known what other species are parasitised by Mutillids, and this is the chief point about which definite and accurate information is required, before the economic value of this family can be determined. Secondly, we should also ascertain the economic position of the parasitised species, *i.e.*, whether they are beneficial, useful, or injurious. The results, based on whatever little has been investigated

by me on the subject, in individual cases, are given below. As aforesaid *Mutilla regia*, Sm., has been bred on *Eumenes conica*, F. This *Eumenes*, we know, stocks her cells with paralysed caterpillars, which are generally injurious insects. *Mutilla regia*, Sm., is therefore an injurious insect in as much as it parasitises an insect beneficial to us. *Mutilla yerburyi* also for similar reasons is an injurious wasp. Next consider the case of *Stenomutilla oglana*, Cam., which has been bred from the cells of *Sceliphron madraspatanum* (Fabr.). *S. madraspatanum* (F.), stores spiders in her cells; spiders are, I think, beneficial to some extent (*vide* my note on the subject under *Sceliphron madraspatanum* (F.), pp. 213—14). It follows from this that the *Mutilla* in question is a beneficial insect in so much as it checks the sprea^d of an injurious one.

FAMILY THYNNIDÆ.

There is practically nothing on record as to the habits of the Indian species of this family, which contains only two Indian genera, *Methoca* and *Iswara*. Of the former only one species, *Methoca bicolor*, Cam., occurs at Pusa, and of the latter we have only one representativ^e *Iswara luteus*, Westw., in our collection, the specimen having [illegible] ken at Sargodha, Punjab, in July 1906.

GENUS METHOCA.

Methoca bicolor, Cam.

The female wasps of this species are wingless and walk about actively like ants, constantly moving the abdomen up and down. The resemblance of this female wasp in shape and colour to the worker of the common black and red tree ant, *Sima rufonigra*, Jerd., is very striking. They differ however in size, the former being constantly smaller than the latter. The doubly constricted thorax of the wasp is easily mistaken for the two abdominal nodes of the ant (Pl. XIV, Figs. 4 and 5).

The name appears to be pre-occupied, having first been used by Say in 1836 (*vide* Boston Journ. Nat. Hist., Vol. I, p. 299). I,

therefore, call this species *Methoca rufonigra*, after the ant which it resembles so closely.

FAMILY SCOLIIDÆ.

There is very little on record as to the habits of the Indian species of this family also. At Pusa representatives of all the genera excepting one (i.e., *Liacos*) are found. *Myzine dimidiata*, Guér., *Scolia quadripustulata* (F.), *Elis annulata* (F.) and *Elis thoracica* (F.) are amongst the commonest species obtained here. During the months of July and August the male wasps are seen in large numbers hovering on flowers, or on grass under the shade of trees, and from March onwards the female wasps are seen flying singly close to the ground, probably in search of beetle grubs, which they have been known elsewhere to parasitise. Only on one occasion, while digging up an ant colony situated on sandy soil where I used to observe *Elis thoracica* hover and disappear in the soil, I secured a hard oval black cocoon, very similar to a dried ball of goat's dung. It did not look at all like a cocoon, and while I was pressing and examining it, it broke in my fingers and the resting larva inside was badly injured.

The cocoon may not be of *Elis thoracica* or of any other Scoliid wasp, but the facts that *Elis thoracica* was constantly flying there and that I obtained cock-chafer grubs (which are believed to be parasitised by the wasps) from the same locality, make it a possibility. However, on such frail grounds I cannot express an opinion.

Relation between Myzine dimidiata Guér. *and M. madraspatana*, Smith.

I have made a series of observations on the above subject. On 1st July 1908 I noticed *Myzine dimidiata* flying in large numbers over dead and dried leaves under a *Sarish* (*Albizzia lebbek*) tree. All the specimens captured proved to be males without any exception. I could not guess what they were about—was it mere frolicking or what? The only thing they did was to sit occasionally on a blade of grass for a couple of minutes and to fly away again.

I watched them daily for some time. On 10th July 1908 I marked *M. madraspatana* ♀ flying there. One *dimidiata* ♂ jumped on her knocking her down and then flew away. Another *dimidiata* ♂ followed suit, but nothing of any consequence happened. This made me suspect some relation between the two. On another occasion I saw a *dimidiata* ♂ sitting quietly over pieces of broken bricks for an unusually long time. I went nearer and saw something moving below. On closer examination it was found to be a winged insect, and when the *dimidiata* flew away I discovered that the hidden wasp was no other than *M. madraspatana*. This incident supported my former conjecture. I continued watching them, and at last on 15th July 1908 I caught *dimidiata* ♂ and *madraspatana* ♀ actually coupled.

Two important conclusions can be drawn from the above observation :—

(*i*) that *M. dimidiata* and *M. madraspatana* are not two distinct species but are male and female of the same species, or

(*ii*) that in this genus males and females of different species can breed together indiscriminately.

I support the first inference for the reason that the late Col. Bingham, in the "Fauna of British India, Hymenoptera," Vol. I, divided the genus *Myzine* in two parts :—

(*A*) Females only known.

(*B*) Males only known.

M. madraspatana is mentioned under *A*. and *M. dimidiata* under *B*.

It appears that these wasps were never captured before "in cop," and since there is not the least resemblance between the two in colour and shape they were described as distinct species. Difference in colour is a matter of no great consequence in the determination of sexes amongst Scoliids. We find in *Elis annulata* ♂ and ♀ another instance of the same kind. The male is smaller and

more slender than the female and bears transverse yellow bands on the posterior margin of the abdominal segments, whereas the female is robust, and black with white pubescence.

FAMILY POMPILIDÆ.

GENUS MACROMERIS.

Macromeris violacea, Lepel.

In the "Fauna of British India, Hymenoptera," Vol. I, the late Col. Bingham remarked regarding this genus as follows :—"The habits of the species belonging to this genus are almost unknown. Once I observed a female carrying a large hairy spider (*Heteropoda venatoria*) to a chink in a deserted wooden house, in the forests in Tenasserim, and there is no doubt she was storing these as food for her future progeny." By the time of the publication of Mr. Lefroy's 'Indian Insect Life' I had obtained only larvæ and pupæ, of this wasp, and the limbs of a spider in one cell. Since then cells containing eggs have also been found, and I have succeeded in studying one life cycle of this interesting and rare wasp which is as follows :—

The female wasp constructs dark brown cells in hollows or under the raised portion of bark of old trees. At one and the same spot as many as half a dozen of these cells may be found. The general shape of these cells is long oval, length about 22 to 26 mm. and breadth about 15 to 17 m m. (Fig. 2). Materials used by the wasp in constructing these cells are various , *e.g.*, clay, sand, chewed

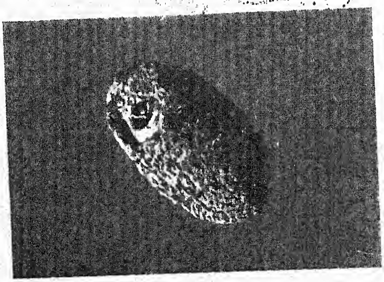
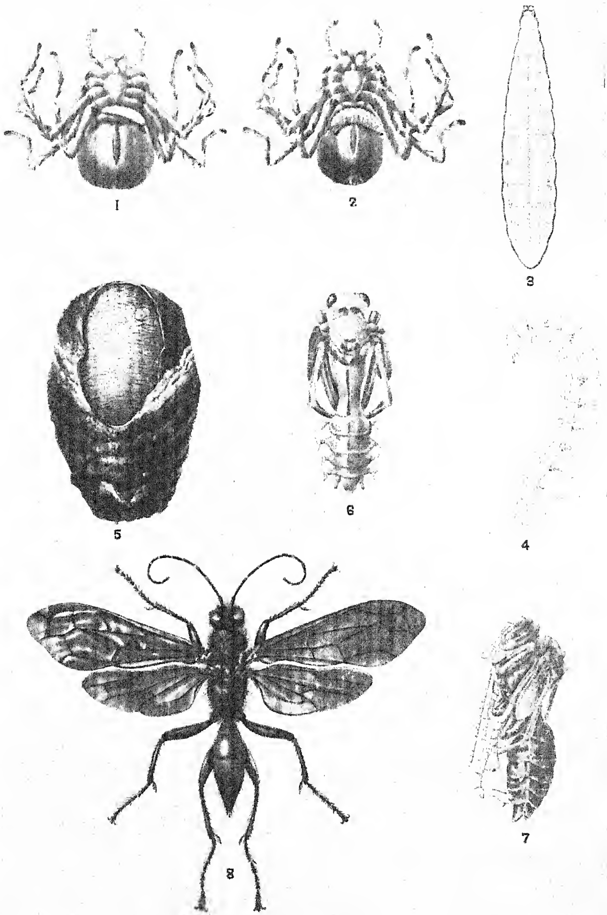


FIG. 2. A CELL OF MACROMERIS VIOLACEA ×1½ (I. I. L.)



MACROMERIS VIOLACEA.

EXPLANATION OF PLATE XI.

Macromeris violacea, Lepel.

1. Spider bearing an egg of the wasp.
2. Two days' old larva of the wasp.
3. Full grown larva, dorsal view.
4. ,, ,, ,, side view.
5. ,, ,, ,, spinning cocoon inside a cell.
6. Pupa, dorsal view.
7. ,, side view.
8. Imago, flying attitude.

All figures magnified × 2.

up vegetable matter, some gummy substance, etc. The outer surface of these cells is rough and rugged, granular and superficially ridged, but the inside is quite smooth. The front near the upper end is flattened and is thinner than the rest of the cell, and it is this portion which is pierced by the wasp at the time of emergence. The lower end of a cell is stuck on one side against the trunk of a tree and the remaining part of the cell stands out at an acute angle.

In each cell a single big spider is stored and on its ventral side near the base of the abdomen is laid an egg. (Pl. XI, Fig. 1). The egg is milky white, long and a little curved ; length is 5 mm. and breadth a little more than 1 mm.

The egg hatches in about 2 days, and the young larva thrusting its mandibles into the abdomen of the spider begins to lap the body juice. The abdomen consequently shrinks and the posterior spinning-mamillæ become distinctly visible (Pl. XI, Fig. 2). As the larva grows it eats voraciously and the spider is completely finished in four days ; nothing but the claws are left. The larva is full grown then and measures when stretched, 28 mm. long and 6 mm. broad (Pl. XI, Fig. 3) ; the head usually remains doubled below the thorax (Pl. XI, Fig. 4). It tapers gradually towards the head end and at the prothorax it is 2·5 mm. wide. The head is wider than the prothorax and is 3 mm. across. It is light brownish in colour and bears two slightly pinkish lines which converge to the vertex. The apical portions of the mandibles are reddish. The body is divided into indistinctly marked segments and is margined laterally. On each side of the body there are 9 circular spiracles. The integument is transparent, and through this white round particles of fat are seen moving forwards and backwards. The general colour of the larva at this stage is greenish gray. The larva spins a brownish cocoon inside which it pupates (Pl. XI, Fig. 5), but before actual pupation takes place it rests for about 5 or 6 days. The colour of the larva in this ‘ resting stage ’ turns to delightful pale yellow and the larva begins to contract a little in size. Below the larval skin becomes visible,

though indistinctly, the future pupa. Ultimately the larval skin is shed and the true pupal stage commences. The pupa is of ivory-white colour and possesses all the limbs of the perfect wasp which are symmetrically folded on the venter (Pl. XI, Figs. 6 and 7). In general form the pupa resembles other Hymenopterous pupæ except in one particular, that the abdominal segments are furnished with lateral 'Y' shaped processes. Of what use are these to the pupa I cannot venture to say definitely, but I fancy that the abdomen when resting inside the cocoon on these 'forks' is very secure. Gradually changes in the colour of the pupa set in from the head side. The eyes turn pinkish to begin with and then blackishness appears on them and also on the thorax. This black colour slowly spreads towards the abdomen till on the 11th or 12th day the whole insect becomes quite black. On the 13th or 14th day after pupation the thin pellicle covering the pupa is shed and the wasp emerges (Pl. XI, Fig. 8). It leaves the cell a day afterwards on getting dry. Thus from egg to imago it occupies about 4 weeks.

Egg stage	2 days.
Larval stage ... ... (including 'Resting stage')	10—11 days.
Pupal stage	14 days.
	26—27 days.

Genus Pseudagenia.

Among the species belonging to this genus those found at Pusa are *P. blanda* (Guér), *P. clypeata*, Bingh., *P. lævicula*, Bingh., *P. ægina* (Smith) and two undetermined species; but none of them is common.

Pseudagenia blanda (Guér.)

Pseudagenia blanda ♀ constructs clay cells in places hidden from external view, such as natural crevices, cavities and hollows in big trees or under their bark, etc. She is strictly a wasp of the jungle, never coming into our houses like *Sceliphron* or *Eumenid* for nest making. There are only two cells in a nest (so far as I have

ascertained) and these are constructed in juxtaposition, one cell being smaller than the other (Pl. XIII, Fig. 3). From the smaller cell emerges the male (Pl. XIII, Fig. 4 & Pl. XIV, Fig. 2), and the female from the larger one (Pl. XIV, Fig., 1). The male cell is 13 m.m. long and the female cell about 17 m.m. These cells are very similar in shape to those of *Sceliphron madraspatanum*, but are constantly smaller in size. One more peculiarity has been noticed in them that near the top there are invariably fixed some clay balls in the shape of knobs (Pl. XIII, Fig. 3). I cannot guess what utility these are to the wasp excepting that they give to the cells more or less the rough appearance of the uneven surface of the bark of trees on which the cells are constructed.

In each cell one spider of medium size is stored, and on the ventral side of the abdomen near the base the egg is laid transversely. The larva, as usual, on hatching feeds on the spider, after consuming which it spins a thin brownish cocoon inside which it pupates. The wasp emerges through a hole made in the top of the cell.

The male wasp of this species does not appear to have been described yet. I, therefore, describe it as under :—

Pseudagenia blanda (Guér.) ♂—(Pl. XIV, Fig. 2).

Head, thorax, and abdomen pruinose; portion behind the eyes, the sides of the pronotum, pleura, and the sides of the median segment covered with longish thin white pubescence, the clypeus large, convex, and its anterior margin slightly sinuate; eyes converging both above and below. Pronotum short, slightly transversely sulcate along the posterior margin; median segment long rounded with a gradual slope to the apex, transverse wavy striations along its middle portion which is without pubescence, its anterior lobe is deeply longitudinally impressed and bears faint transverse striations; legs long without spines, calcaria of the hind tibiæ about as long as the 2nd tarsal joint, abdomen fusiform. Bluish (in certain strong lights black with a bluish bloom) with a thin silvery pile; the palpi, labrum, mandibles at apex, clypeus

except a dark brown spot in the centre, face to a little above the base of the antenna in the middle and up to the vertex along the inner orbits of the eyes, the scape of the antenna in front, all the coxæ in front, apical margins of segments 1 to 6 of the abdomen narrowly, and the hypopygium two large lateral spots on the 7th segment, yellowish white; abdomen black with a bluish bloom; base of the mandibles and antennæ black; the femora orange red, the tibiæ and tarsi dusky brownish black; wings hyaline and iridescent, apex of the forewing narrowly fuscous; nervures and tegulæ testaceous.

Length 8·5 mm. Exp. 14 mm.

Economic.—This wasp constructs cells in pairs, but it is not known how many such pairs are built by one wasp. If after constructing the first pair of cells, she dies or is incapable of laying more eggs, I should class her as neutral from an economic point of view. We have seen she lays up a single spider in a cell, and as this wasp is never abundant at any time of the year, the number of spiders destroyed is insignificantly small. Consequently the harm done by this wasp is negligible.

Pseudagenia clypeata, Bingh.

The nesting habits of this wasp are very interesting, and I cannot do better than quote here one of my observations on the subject.

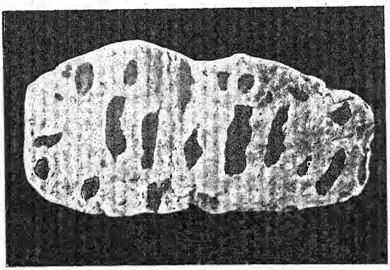


FIG. 3. NEST OF SCELIPHRON COROMANDELICUM OCCUPIED BY PSEUDAGENIA CLYPEATA × ½ (I. I. L.

"From a very big clay nest (Fig. 3), removed from a hollow in a tree, emerged *Pseudagenia clypeata*, male and female. The nest appeared to be decidedly that of some *Sceliphron* wasp, probably of *S. coromandelicum*

(Lepel), but the emergence of the *Pseudagenia*, which is not a parasite, was indeed puzzling.

"The first essential thing to determine was what species had originally constructed the nest. Of all the mud-nest constructing wasps found at Pusa, *Sceliphron coromandelicum* alone could make such a big nest. However to ascertain this I closely examined the underside of the nest. If it were actually the nest of *Sceliphron coromandelicum*, I argued, there must have been a few large cells of equal size more or less in a line. No doubt there was one big empty cell visible on the underside. On the right hand side of this cell I removed a little clay with a knife; a cavity appeared, and I opened it little by little till the cavity proved to be another cell (of the same size as the first one) containing broken limbs of spiders. Similarly on the left hand side of the 1st cell I opened another cell of the same size containing dried and broken limbs of a wasp, but from these broken limbs, the wasp could not be definitely determined. Thus seven cells were discovered in one line, and from one of these I obtained a rotten specimen of *Sceliphron coromandelicum* covered with fungus growth. This decided one point.

"Again, in some of the cells I found empty brown cocoons of the *Sceliphron* containing small clay cells in which were seen thin yellowish empty or inhabited cocoons.

"In some cases in a single cell of the *Sceliphron* there were noticed two smaller clay cells, each containing a full grown larva or a pupa in a thin yellowish cocoon. Again, all round these seven cells and on the margin of the big nest, smaller cells containing the above mentioned larvæ and pupæ in cocoons were discovered.

"From the above mentioned facts I conclude:—

1. That the nest was originally constructed by *Sceliphron coromandelicum*;

2. That when the wasps had emerged from almost all the cells the empty cells were utilized by *Pseudagenia clypeata* for nesting;

3. That when all the empty cells were occupied more cells were added on to the margin all round." *

It may be interesting to know how to distinguish externally a *coromandelicum* nest occupied by *P. clypeata* from a nest which is unoccupied. The test is simple : *Sceliphron coromandelicum* is a much bigger and stouter wasp than *Pseudagenia clypeata*. Naturally enough the former is capable of carrying much greater quantity of mud at one time than the latter. Thus when mud pellets are thrown at random on the completion of the nest by the *Sceliphron*, the nest assumes an ugly appearance of one lump of mud, whereas the *Pseudagenia* covers the outer surface of the nest all over with fine small round clay balls which are laid regularly side by side (Plate XIII, Figs. 1 & 2).

In a cell of *Pseudagenia clypeata* only one spider of a moderate size is stored. On the underside of the abdomen of the spider the egg is placed transversely, and not inclined to one side of the abdomen as in the case of *Sceliphron* wasps. *P. clypeata* takes particular care to bite off the spider's legs before egg laying ; thus minimizing the chances of destruction of the egg from the leg strokes of the spider administered during moments of convulsive agony, and ensuring to some extent the security of the larva from similar disaster when it is biting into the abdomen of its victim.

The egg is about 2 m.m. long and 0·4 m.m. broad ; white, long and cylindrical with ends rounded. About 6 days after hatching the larva finishes its spider and is full grown. It measures then 9 m.m. long and 2 m.m. broad (one larva measured 10 m.m. long and 3 m.m. broad ; probably this was the larva from which a female wasp was to emerge). General colour of the larva is gray. It looks very similar to the larva of *Sceliphron madraspatanum* in colour and general appearance. The integument is thin and transparent, and through it are visible round white particles

* NOTE.—In July 1909 I removed from a tree a mud nest of *Sceliphron coromandelicum* from which emerged both the wasps *Sceliphron coromandelicum*, and *Pseudagenia clypeata*. It shows that the *Pseudagenia* does not necessarily wait till all the wasps from the cells of a nest have emerged, but occupies or adds her cells on to it even if some of the cells are inhabited by the *Sceliphron* larvæ or pupæ.

(of fat) moving to and fro. The prothorax has not those fleshy tubercles which are so conspicuous in *Sceliphron madraspatanum* (F.) larvæ. That portion of the body representing the abdominal segments is margined laterally and the marginal area is indented, bearing blunt fleshy triangular tubercles. There are 14 segments of the body including the head which is bigger and broader than each of the three succeeding thoracic segments and smaller and narrower than the central ones. On the front there are two slanting brownish lines converging towards the vertex.

The full-grown larva spins a thin yellowish brown cocoon inside which it rests and pupates. As soon as spinning is finished the larva discharges excreta which do not form a long continuous mass as in the case of *Sceliphron* larvæ, but a string of pointed beads. *

Enemies.—Two parasites have been bred from *Pseudagenia clypeata*, one Hymenopterous (Ichneumonidæ) and the other Dipterous (*Hyperalonia* sp.) The full-grown larva of the former spins a separate thin white cocoon in the cell of the host, while the latter pupates inside the wasp cocoon. Once the *Hyperalonia* maggot gets at the wasp larva, the former finishes the latter within three or four days' time and rapidly increases in size (Fig. 4). When full grown its length is 11·5 m.m. and breadth 3 m.m. at its widest portion. General colour is yellowish white. The distinctly marked segments of the body are ten ; but on taking into account the faint transverse impressions, on the ventral surface, they number twelve. The anterior portion is rounded, smooth. There are no mouth parts visible, but just in the centre on the front side, there is seen (under a microscope, of course) a thin curved beak-like process, reddish-brown in colour. On either side of the 1st anterior segment is visible a spiracle, semi-circular in shape. On the last segment but one on either side, there is another spiracle circular in form. The integument is very thin and transparent. Below are almost round white particles of fat accumulated together and arranged

* NOTE.—This holds good only when larvæ are put in an open glass crucible where they cannot spin a regular cocoon.

in beautiful indented patterns near the middle portion of the segments. The full grown maggot rests inside the *Pseudagenia* cocoon in a curved position. Resting period lasts from 5 to 6 days in summer, after which the maggot casts off its skin; and this is an indication that the pupal stage has commenced. The pupa is quite a curious object. It has no similarity either with the maggot or the fly. The head end is furnished with 8 spines, the tail with two, the body with long reddish brown hair, and the middle segments above with backwardly-pointing thick short spines. There are eight ear-shaped spiracles on either side of the body; but there are no spiracles on the first and last segments (reckoning from the head end). The pupa is of a yellow colour in the beginning (excepting the spines and hair which are reddish brown), but gradually the head, thoracic segments (and wing pads) turn dark brown and become darker till just before emergence of the fly these parts become very dark brown approaching to blackness.

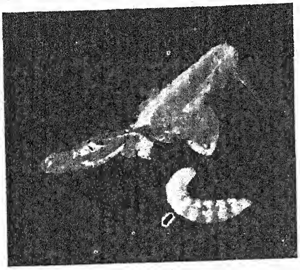


FIG. 4. LARVA OF HYPERALONIA SP. IN RESTING STAGE, LYING NEAR THE DESTROYED PSEUDAGENIA LARVA SHOWN ABOVE IT ×2 (I. I. L.)

The pupal stage lasts for 12 days in summer. Emergence takes place just in the same way as in the case of *Hyperalonia sphynx*, described under *Sceliphron madraspatanum.* But one thing is worth mentioning; when the pupa is lying in a glass crucible on one side, it turns on its back at the time of the emergence of the fly, thus resting on the backwardly-pointing spines with which its back is furnished.

Economic.—Although this wasp also stores a single spider in a cell, yet I will put it down as an injurious insect; for in a single nest there may be as many as eighteen (more or less) cells which means destruction of an equal number of spiders in one brood. In

the following brood there will probably be six females (allowing one-third the number as parasitised and one-half of the remainder as males), each paralysing 18 (more or less) spiders. Similarly in the next brood from each of these six nests six female wasps will emerge, each storing 18 spiders in her nest. Thus there will be an enormous number of spiders paralysed and destroyed by this wasp during a year. The spiders stored in cells being the web-spinning species are useful (*vide* my remarks on the subject under *Sceliphron madraspatanum*).

Pseudagenia spp.

Four clay nests, consisting of small delicate cylindrical cells arranged in double rows were removed from the trunk of a Pipal tree in July 1909 (Pl. XIII, Fig. 5). The largest nest contained eleven cells. Each cell measured 9 to 10 m.m. long and about 3 m.m. broad. Only one spider was stored in a cell and an egg laid on its abdomen, and in this respect it agreed with *Pseudagenia clypeata* and *Pseudagenia blanda*. Males and females of an undescribed species of *Pseudagenia* emerged from these cells (Pl. XIII, Fig. 6).

In March 1909 I found a big deserted nest of *Sceliphron coromandelicum* constructed in a hollow of a tree. All the cells but one were empty. This one cell did not contain the *Sceliphron* larva or pupa, but was found to be inhabited by the pupæ of a *Pompilid* wasp (*Pseudagenia*). The cell was divided into four smaller cells, and in each was found a pupa encased in a cream coloured thin cocoon. An undescribed species of *Pseudagenia* emerged from these also.

Aporus cotesi, Cam.

These tiny active Pompiliid wasps are commonly seen at Pusa during March, each year, on sandy soil by the riverside, chasing small ground spiders. Their nests are probably under ground and are stocked with spiders. On 14th June 1909 I dug out one cocoon of this wasp. On opening this I found the larva ‘ resting ’ inside, and in this state it remained for over two months. The cocoon was of a reddish brown colour and club shaped.

Size :—Length 16 m.m. and
Breadth 3·5 m.m. at the widest part.

The wasp emerged on 27th August, 1909.

FAMILY SPHEGIDÆ.

This is a very large family containing nearly 40 Indian genera, representatives of nearly all of which are found at Pusa. The genus *Sceliphron* alone has been studied in detail, but a few observations concerning the habits of other wasps of this family have also been made and these are recorded here.

Notogonia subtessellata (Smith).

I have nothing in particular to add to the habits of this wasp given in "Indian Insect Life," but I may quote here one or two observations from my Note-book dealing with the subject in detail.

Pusa—13th Feb., 1908.

"Noticed *Notogonia subtessellata* ♀ flying on sandy soil, on the left bank of the river. She selected a spot and began digging there. A small hole was dug up in the beginning and then she removed the loose soil; went into the hole a second time, dug further down, and came out again with loose soil. (The anterior legs are turned into a loop to carry the soil out). This soil was heaped up close to the mouth of the hole, but as the heap assumed an appreciable height, she got to the top and demolished it by kicking away the soil by her hind legs, to prevent its falling back into the hole. She must have been digging for about five minutes when, from a hole just close to the one dug out by the wasp, there jumped out a small white immature cricket. The wasp was inside the hole, but she somehow learnt that her prey had escaped; the cricket came to the place where I was standing and hid itself under my glass topped box which was lying on the ground. The wasp also hastily came out of the hole, and finding another hole close by entered into it. I got hold of the cricket and thrust it in the hole behind her. It jumped out again, but was closely pursued by the

wasp. The cricket showed much agility, but was in a moment in the grasp of the wasp. She stung it on the under-side, near the pro-mesosternal suture. As soon as the poison was injected the cricket, which was so active just a minute before, lay motionless, though not dead. The wasp left it and surveyed it probably with a sense of relief and satisfaction. Presently she jumped on its back, and, grasping an antenna, sat as if in a riding posture. She took four or five one-foot flights with the heavy load and ultimately flew away from my sight behind the Tur plants which were growing thick close to the field where I made this observation."

"Another *N. subtessellata* dug out a cricket from its burrow, stung it and carried it to its nest which was situated in sandy soil under ground. Just close to this nest she alighted from the back of the cricket, caught hold of an antenna and entered the nest moving backwards facing the cricket."

Multan City (PUNJAB), 14th April 1908.

"At the foot of a wall there was a hole, in which I noticed *Liris hæmorrhoidalis*, Guér, entering with a big ground cricket. As the wasp is very pretty and not found at Pusa, I was anxious to obtain this specimen. I could not remove the bricks and the plaster from the wall, and the only way to get it, I could think of, was to place my killing tube at the mouth of the hole. After 15 minutes, on looking to my tube I was astonished to find a specimen of *Notogonia subtessellata*, with the desired specimen of *Liris*, in it. Whether the *Notogonia* had been by mere chance to the hole of *Liris*, or there were two separate chambers with a common entrance, or the former had entered into the nest of the latter with a view to steal away the stored crickets or to lay eggs on them, I cannot definitely say. But it is an interesting fact to record."

Pison erythropus, Kohl.

Early in November 1908 I collected some small cylindrical clay cells which were entangled in the cobweb of a spider high up on a tree. The cells were very delicate and broke under the slightest

pressure of the fingers. Both the ends of the cells were rounded and each cell measured about 9 mm. long and 4 mm. broad. On opening up a cell I got about 30 minute spiders and a tiny little larva feeding on them. It was no small wonder to behold so many spiders packed together in so small a compass. The larva when full-grown spun a rather tough dirty brown cocoon, the lower end of which turned darker as the larva deposited excrement at the bottom. Each cocoon measured 8 mm. long and 4 mm. across, cylindrical in shape, with ends rounded. The larva hibernated throughout the winter and on 18th March 1909 several wasps emerged. The hibernating larva, like *Sceliphron* larvæ, lies doubled up inside the cocoon.

On another occasion (in June 1911) I saw these cells constructed close to the white silken cocoon in which spiders enclose their eggs.

In a nest there are from 6 to 12 cells, and in each cell about 36 minute spiders are stored. Taking nine as the average number of cells in a nest it would be necessary for the wasp to paralyse at least 324 spiders, a number which is not easy to secure. It is for this reason that we find the cells of this wasp close to or on the spider webs, so that she may not have to go far away in quest of her prey. The white silken cocoon mentioned above was found to contain only the empty egg shells and the wasp larvæ inside the cells had pupated. It appears that the wasp selected this site for her nest at the time when the eggs were just hatching.

For reasons discussed under *Sceliphron madraspatanum* I do not consider this wasp to be a beneficial one.

Trypoxylon pileatum ♀ (Smith).

This wasp, so far I have seen, very seldom constructs a nest of her own. It generally occupies empty reeds, thatch, dry empty branches of the Ak plant (*Calotropis* sp.) and of the Pipal tree (*Ficus* sp.) which once contained the cells of the green bee *Ceratina viridissima,* Dall. Torr. Once I saw this wasp making a cell in the folds of a newspaper, and this has been observed by the late Col.

Bingham also (*vide* "Fauna of British India, Hymenoptera," Vol. I, p. 223). It always takes advantage of ready-made holes, and natural cavities, which are simply partitioned off into cells by round mud plugs. In very rare cases the female has been observed removing dry soft pithy substance from a dry branch of a tree or of a plant for nesting.

In each cell paralysed spiders are stored, on which the larva feeds. Fig. 5 shows this wasp bringing a spider to her nest in a hollow stem. When full-grown the larva spins a thin brownish cocoon inside which it pupates. The pupal stage lasts for about 12 days. A few days prior to the emergence of the wasp the pupa develops on either side of the three basal abdominal segments white crescentric marks which remain visible for at least two days even after the emergence of the wasp.

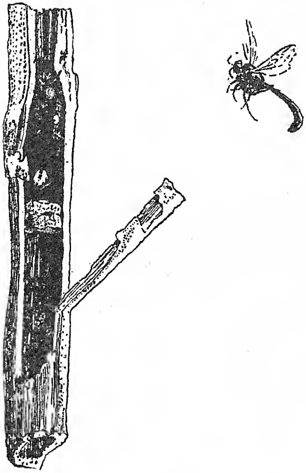


FIG. 5. TRYPOXYLON PILEATUM BRINGING A SPIDER TO HER NEST IN A HOLLOW STEM; THE NEST HAS BEEN OPENED TO SHOW THE CELLS. (I. I. L.)

An undescribed species of this genus, very similar in habits to *T. pileatum*, has been bred here from cells in reed and thatch. The largest number of cells found as yet in a nest of this species has been twelve. The pupæ are encased in thin brownish yellow cocoons which are 7 mm. in length and 2 mm. across.

The spiders stored in both these cases are the web-spinning species. These I understand to be useful to some extent for the reasons discussed under *Sceliphron madraspatanum*. These wasps I consequently class as injurious insects.

Genus Ammophila.

The undernoted species of this Genus are common at Pusa:—

1. *Ammophila basalis*, Smith.
2. *Ammophila nigripes*, Smith.
3. *Ammophila lævigata*, Smith.

The habits of *Ammophila lævigata*, Sm., have been described in "Indian Insect Pests," pp. 271-272, and need not be reproduced here. The remaining wasps also behave similarly. These wasps appear each year as early as April and remain active till October, but are commonly met with only during August and September when they are seen hunting caterpillars in the fields. Since these prey upon caterpillars, they are decidedly beneficial insects.

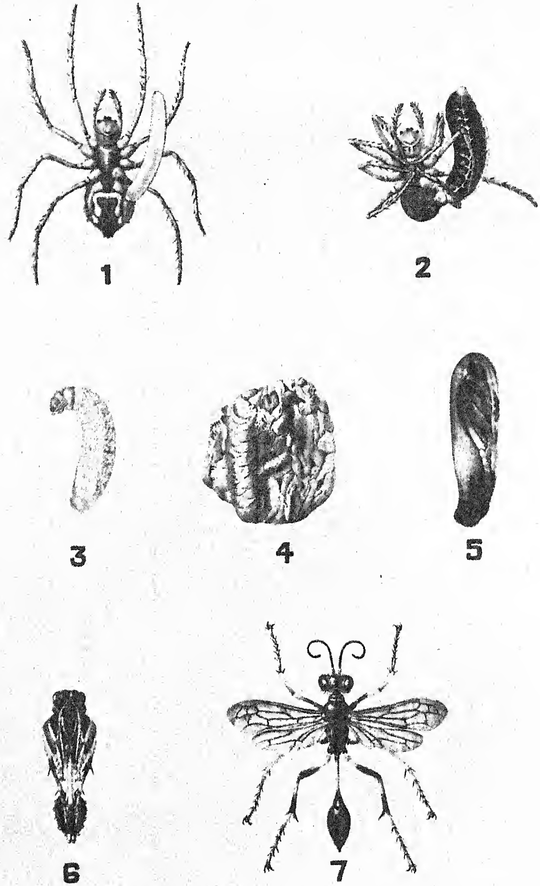
Genus Sceliphron.

Sceliphron madraspatanum (Fabr.).

The female wasp constructs mud nests consisting of 2 to 7 long narrow semi-cylindrical cells, in the corners of houses, in wooden furniture, etc., etc. These cells are stored with spiders, and each cell may contain about 18 spiders or a few more or less.

Length of a cell externally, top to bottom is 27—30 mm. Length of actual cavity inside is 19—20 mm. and width 6 mm.

A cell is raised to the necessary height in the first instance and the mouth above is left unclosed. Next, paralysed spiders are brought in one by one till the required number to be stored is reached. The mouth of the cell is then closed with a mud plug and another cell is started in the same way. Cells, when just completed, show some evidences of skill in architectural design (Pl. XIII, fig. 8), but when the whole nest is finished, mud pellets are thrown over it at random making it look like a mere lump of mud (Fig. 6). Horne says "on one occasion I observed rays of mud round the nest even more exactly imitating a lump of mud thrown with some force. This I hold to evince a most wonderful instinct as they could not be required for strength." (Trans. Zool. Soc. VII, p. 163, 1870). I have also noticed these streaks, but in very rare cases. I think Horne has attributed more than is *Sceliphron's* due. What happens is simply



SCELIPHRON MADRASPATANUM.

EXPLANATION OF PLATE XII.

Sceliphron madraspatanum.

1. A Spider bearing an egg of the wasp on the ventral side × 8.
2. „ „ a two days' old wasp larva × 8.
3. Full grown larva, side view × 2.
4. A partly finished nest of the wasp × natural size.
5. Pupa, inside cocoon × 2.
6. Pupa, ventral view × 2.
7. Wasp drawn from a pinned specimen × 2.

this, that if some one is watching the nest from close quarters and the wasp returns in the meanwhile with a mud pellet, instead of alighting directly on the nest she alights some distance away. Being "fearless when engaged in cell building" (to quote Horne's words) she boldly walks up to the nest with the wet mud ball (held between the forelegs and the mouth) touching against the wall. It is thus that the mud rays are traced on the wall converging to the nest from different sides. I am therefore of opinion that the presence of mud streaks is not suggestive of any wonderful instinct, but is the result of mere chance.

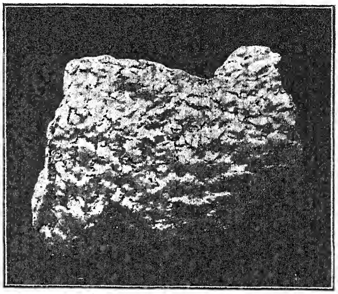


FIG. 6. FINISHED NEST OF SCELIPHRON MADRASPATANUM. (FROM A PHOTOGRAPH).

The egg is deposited on the 1st spider brought into a cell and is laid obliquely across its abdomen near the base, in such a way as to enable the young larva to eat into the soft portion of the abdomen (Pl. XII, Fig. 1). Should the egg be laid in a cell and the required number of spiders not stored before dusk, the *Sceliphron* puts a temporary clay covering on the mouth of the cell for the night, and this is taken off the following morning. At night the *Sceliphron* is never seen on or near the nest. Early in the morning or at dusk these wasps can be seen sleeping on the leaves of bushes.

The egg is white, semi-transparent; in shape long, cylindrical with ends rounded. Length is about 3 mm. and breadth 0·8 mm. Before hatching the colour changes to uniform milky white and is opaque. This stage lasts for one to two days.

The larva on hatching remains in exactly the same position and locality as the egg. The only thing which readily distinguishes it from the egg is the prominent constriction separating the head from the rest of the body. In length it is a little more than 4 mm.

and it is white in colour. The body is indistinctly divided into segments of which those in the middle are clearly marked. It commences to feed on that part of the abdomen where it finds its mandibles in contact with the skin of the spider. Finishing this spider it attacks the next one above it. Thus it works its way upwards devouring one after another all the spiders stored in a cell (Fig. 7).*

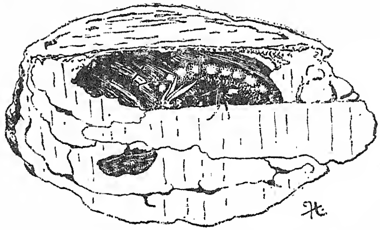


FIG. 7. SCELIPHRON MADRASPATANUM NEST REMOVED FROM A CORNER, AND SEEN FROM BEHIND ; LARVA FEEDING ON A SPIDER. (I. I. L.)

The colour of the whole body undergoes a gradual change. First it becomes dirty white, then changes by degrees to gray, excepting the head, one or two succeeding segments and one or two terminal segments, which are all yellow.

In size it increases at the rate given below :—

1st day length 4·5 mm....	White ; indistinct ridges on the body.
2nd day „ 5· mm. ...	Much broader than before. Head and margin of the body white, rest grayish.
Afternoon.	Body more gray.
3rd day length 6· mm. ...	Colour same ; integument transparent.
4th day „ 9· mm. ..	Head and apical segments yellow, margin dirty white, rest of the body gray ; very much broader than before.
Afternoon.	length 10·5 mm.
5th day length about ...	... 12 mm.
6th day „ ...	.. 13·8 mm.
7th day „ ...	... 14 mm. full grown.

* NOTE.—It is for this reason that we always find a larva of this wasp head upwards in a cell.

The development is rather rapid after the 3rd or 4th day and on the 5th or 6th day it attains the length of 12 mm. and, when full-grown (in a week's time), it measures about 14 mm. long and 3 mm. broad in its widest part.

Full-grown larva.—Its general colour at this stage is gray; head yellowish, apical two segments yellow and mandibles ferruginous. The integument is soft and from above semi-transparent, and through it are visible white particles of fat moving backwards and forwards. The body is broadest in the middle, and narrows both anteriorly and posteriorly. It is margined on both sides; margin very protuberant, yellowish in colour. On each side of the body there are 10 small circular spiracles of ⊙ shape. The body is divided into 14 segments, the middle ones are distinct and deeply cut. The segment representing the prothorax has four or five fleshy triangular (more or less conical) tubercles. The head is usually doubled below the thorax. (Pl. XII, Fig. 3.)

It has been observed that the larva moults several times before it attains full length, but the exact number of moults it passes through could not be ascertained, for the larva is in the habit of eating away the skin as soon as it is loosened, leaving behind no trace of the moult.

When full-grown the larva begins to spin a cocoon of light yellow silken threads which turn brown afterwards; the threads are so thickly and closely laid that the cocoon looks as if made of brown papery material. The cocoon is long oval, narrow towards the bottom; the top is rounded, and it is as broad there as in the middle. Length is about 19 mm. (Pl. XII, Fig. 5.) When the cocoon is spun, the larva pushes out through the anal tube a black mass of excreta, which is deposited at the bottom of the cocoon. (In empty cocoons obtained from old nests it is found as a black hard substance at the bottom. In case part of the excreta remains sticking in the terminal segment of the body, and is not completely discharged, the larva is sure to die either before or after pupation.) The colour of the larva is changed to yellow, the body is divided into deeply cut segments with protuberant margins, which on account

of the deeply marked divisions have the appearance of fleshy tubercles on the sides. The larva becomes more compact, decreases in length, but becomes broader. The length is about 10 mm., breadth about 4 mm. It loses its activity and remains motionless inside the cocoon for a period which extends over 3 to 6 days in summer and early autumn. This stage I term the "resting stage."

Pupa.—The 6th segment of the body, reckoned from and including the head, becomes narrow prior to casting off the larval skin which may take place 11 to 15 days after hatching. This cast skin in some cases remains sticking in a rolled-up state to the apex of the abdomen. All the limbs of the perfect wasp appear with the shedding of the larval skin; the antennæ, mouth-parts and legs are symmetrically folded on the ventral surface (Plate XII, Fig. 6); and this appears to be a constant feature with all Hymenopterous insects (Aculeates).

In a fresh pupa the abdomen is not connected with the thorax by a narrow stalk but is joined on broadly, as we find in Sessiliventres (Adults); consequently the length of the fresh pupa is short (about 10 mm.). The region between the abdomen and thorax begins to be narrowed gradually, and after two days the petiole assumes its ultimate dimensions and the pupa attains the length of about 14 mm. The pupa is of a whitish pale colour, the mouth parts excepting mandibles, antennal joints, tarsal joints and petiole being white. A gradual change in the colouration of the pupa sets in and is first exhibited by the eyes, which assume a pinkish tinge 2 or 3 days after pupation. This colour changes to dark red, then to slate colour and finally to black. The colour of the thorax also undergoes a gradual change. On the 7th day of pupation the head and thorax down to the apex of the median segment and legs in parts become black excepting a medially interrupted line on the prothorax and a line on the scutellum which are yellow. On the 8th day the abdomen also becomes black; the whitish yellow or pale colour of the remaining limbs of the pupa turns yellow on the 11th day. Wings up to this stage remain undeveloped. In their place are seen thick pads of delicate skin covering the meso- and metapleuræ.

The pupa is covered by a thin transparent pellicle which is cast off on the 11th or 13th day after pupation and the perfect wasp with long graceful wings emerges. The wings are delicate but get harder as they dry. The wasp pierces the brown cocoon in which it is encased and then removes the mud plug put on the top of the cell. A neat circular hole is formed and the wasp escapes through it.

Thus the whole life cycle occupies about four weeks.

Egg stage	From 1 to 2	days.
Larval ,, (including "resting stage")	,, 11 to 15	,,
Pupal stage	,, 11 to 13	,,
Total ...	From 23 to 30 days.	

Nests for the last brood are constructed in the middle of October, the winter and the early part of spring being passed in hibernation, which takes place in the 'resting stage.' Wasps emerge towards the end of the following March, and the cycle is commenced again. Thus beginning with April up to the middle of October this wasp runs through seven complete broods.

In the middle of October 1910, I collected a nest containing about 10 cells from which four wasps and one Ichneumon parasite emerged in November 1910. On opening the remaining cells larvæ were found hibernating in them. Wasps from these emerged in the last week of March 1911. During four years this was the only instance I came across in which half the inmates of a nest emerged at one time and the remaining half after five months.

Enemies.—The following parasites have been reared from the cells of this species :—

I.	Chrysid wasp	.. *Chrysis* sp. near *fuscipennis.*
II.	Tachinid flies	.. Species undetermined.
III.	Bombyliid flies	.. *Hyperalonia sphynx* and *Argyramœba distigma.*
IV.	Mutillid ant	.. *Mutilla* sp. near '*oglana.*'
V.	Mordellid beetle	.. Species undetermined.
VI.	Ichneumon fly	..
VII.	Strepsiptera	..

I. Chrysid Parasite.

On opening up a cell parasitised by No. 1, we get some dried spiders and below them *at the bottom of the cell* a larva or a pupa covered by a brownish tough cocoon.

The Chrysid larva attacks the *Sceliphron* larva when the latter is a few days old. On finishing it up, it spins a cocoon inside which it rests for some days prior to pupating. On casting off the larval skin the pupa shows all the limbs of the perfect wasp and is of a pale yellow colour. Then gradual changes in the colouration of the pupa occur, as described above in the case of *S. madraspatanum*. The eyes show signs of change first. They become pinkish and this colour passing through successive intermediate stages of changes, turns ultimately black. The thorax and abdomen then develop some sordid pinkishness which changes to a greenish tinge. Day after day the insect grows more and more green, golden green and blue in parts till the thin pellicle covering the pupa is gradually rolled up, and the perfect wasp piercing the cocoon emerges through the top of the cell.

It will be interesting to note that Chrysid larvæ go into hibernation at just about the same time as the *Sceliphron* larvæ do, and the time of emergence of both is also nearly the same.

II. Tachinid Flies.

In the cell parasitised by No. 2 we find only dried limbs of spiders. There are also found either dirty white maggots tapering anteriorly or reddish brown cylindrical puparia which may be as many as six in a cell.

So far I have not succeeded in getting eggs of the Tachinid fly in a cell, nor have I personally observed how these are laid inside it. On more than one occasion, however, I have found very young maggots in cells which had just been closed.

These maggots are found generally (in freshly constructed cells) on the abdomen of that spider which lies at the bottom of a cell, and on which the wasp lays her egg. A freshly hatched maggot measures about 1 mm. in length, is dirty white, and tapers anteriorly, and is

truncate posteriorly. Gradually it increases in length and changes its colour day after day, till it is full-grown (9 mm. or more) and the colour becomes once again dirty white, after having gone through a series of changes, *e.g.*, dirty white for first three days, dirty black on 4th, on 5th dirty brown, and then dirty rusty brown from above and sides white; on the sixth day whitishness goes on increasing and brownish colour decreases proportionately, till on the 8th day whitishness spreads all over the body of the maggot.

Usually on the 9th day after hatching pupation takes place. The maggot becomes compact and decreases in length, the tapering end is drawn in telescopically and the whole long thick tapering mass turns into a small cylinder (a little curved inwards)—with ends rounded, of pale testaceous colour (which gradually changes to dark reddish brown afterwards), very smooth and shining. It is 5·5 mm. long, 2·2 to 3 mm. broad. This is known as the "puparium" and it encloses the true pupa.

The pupal stage lasts from 10 to 12 days. The Tachinid fly does not possess the strong mandibles of a wasp to cut open a passage through the puparium, but Nature has supplied this want with what is known as a "Ptilinum." This is an inflatable balloon-like organ capable of being thrust out through a frontal suture just above the base of the antennæ. When the fly is about to emerge from the pupa case, this balloon expands and pushes off the end of the puparium, thus making an exit for the fly to escape through. The fly on coming out is only able to walk or hop, it cannot fly, for the wings are not expanded. When the Ptilinum resumes its original position inside the suture some moisture inwardly reaches the wing pad, and the wings, on being relaxed, open, if not otherwise damaged.

I collected a nest of *Sceliphron madraspatanum* in the middle of October 1908 and kept it under observation in a glass-topped box. Wasps from this emerged on 28th, 29th and 30th March 1909. Still there were one or two cells out of which nothing had emerged. It was surmised that either the wasp larvæ had gone bad inside the cells or they had been parasitised. But Chrysid parasites had come out long ago, Bombyliids were still emerging (June 1909), though

not from *Sceliphron* yet from *Pseudagenia* cells. I was surprised, however, to find a Tachinid fly emerging from the nest on 4th June 1909. This points to an important conclusion that Tachinids (parasitic in the cells of *Sceliphron madraspatanum*) hibernate during the whole of winter, spring, and a part of the hot weather also.

One more interesting point in this connection. I should better quote it *verbatim* from my observation-book.

"Last year (1908) when as many as half a dozen puparia were obtained from a single cell of *Sceliphron madraspatanum*, I wondered how so many maggots could be nourished on one small wasp larva. This year (1909), on 15th June, I removed a nest consisting of three cells; the third cell was not yet closed. On the abdomen of a spider found at the bottom of one of these cells I got six Tachinid maggots just at the place where the wasp egg is ordinarily found. No trace, however, was left of the egg there. It must have been consumed by the maggots which having finished it were now eating into the abdomen of the spider. When this spider was finished I gave them another and thus they consumed 12 spiders one after another before they pupated. This clears the whole point. The Tachinid maggots live chiefly on the spiders placed in the *Sceliphron* cells. The Tachinid, therefore, is a serious enemy of *Sceliphron*, for it proves destructive to its larvæ in two ways, either by directly eating it up or by starving it, should it escape anyhow.

III. *Hyperalonia sphynx.*

I have not yet been able to secure an egg or a larva of this fly. Only pupæ were found in the two nests from which were bred these flies. Consequently I do not know anything about the egg-laying habit of this fly, nor can I give a description of its larva.

Another *Hyperalonia* sp. (allied to the above species) has been found to be parasitic on *Pseudagenia blunda*, a Pompilid wasp. Since both the *Hyperalonias* resemble one another very much in the adult stage, it is quite probable that their larvæ also agree. A *Hyperalonia* larva parasitic on *Pseudagenia* has been described in its proper place (p. 195).

Pupa.—Length 11·5 mm. The general colour is dirty yellow. It has a brownish yellow covering (of harder skin) over the head and the following two segments of body (dorsal) and three segments (ventral). This covering bears eight sharp spines arranged in three rows :—

(*a*) Two in the 1st row (on the ventral side).

(*b*) Four in the 2nd row (in front).

(*c*) Two in the 3rd row (in front, just above those of the 2nd row).

On all the segments above there are minuter but sharper spines pointing backwards, and their apex slightly curved upwards. These spines are longer and finer on segments 4, 5 and 6 (reckoned from headside) than on any other. The last segment also has two spines pointing backwards and curved slightly upwards. There are long rather stiff hairs on the body (fig. 8).

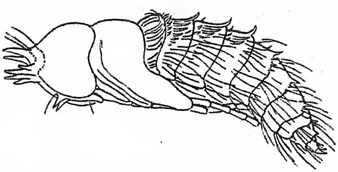


FIG. 8. PUPA OF HYPERALONIA SPHYNX SHOWING SPINES.

The pupa is broadest in the middle, gradually narrowing posteriorly. It is found inside the brown cocoon in which the full-grown wasp larva rests before pupating, inside this cocoon nothing is left of the wasp larva excepting the hardened black excrement discharged by the full-grown larva prior to abandoning its active life.

When the Bombyliid fly is about to emerge the pupa makes a hole in the mud nest by means of the sharp spines with which it is provided anteriorly, wriggles out a little, and fixes itself there by means of the sharp and backwardly pointing spines with which its

body is furnished. The pupa skin bursts and the fly emerges, leaving behind the empty pupa skin projecting out from the hole (Fig. 9).

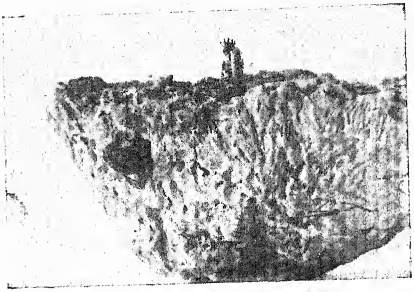


FIG. 9. PUPA SKINS OF HYPERALONIA SPHYNX IN NEST OF SCELIPHRON MADRASPATANUM ×2 (I. I. L.)

Argyramœba distigma.—This fly was bred once in August 1908. and again in March 1909 from the hibernating larvæ of *Sceliphron madraspatanum.* Its mode of emergence from the nest is exactly the same as described above in the case of *Hyperalonia.*

IV. *Mutillid Wasp, Stenomutilla oglana*, Cam.

These wasps were reared from the cells of *S. madraspatanum* twice (*i*) in August 1908 and (*ii*) in September and October 1908. Unfortunately only males emerged on both occasions.

V. From a nest collected in September 1909 from a hole in the trunk of an old Pipal (*Ficus religiosa*) tree was bred a Mordellid beetle (species undetermined).

VI. An Ichneumon exactly similar to the species bred on *Pseudagenia clypeata* Bingh. was reared from the cells collected in October 1910.

VII. At Pusa up till 1910 *Polistes hebræus*, F., alone had been found infested with Strepsiptera, but in March 1910 when *Sceliphron* wasps emerged after completing their hibernation period they

also were found to carry in their abdomen male pupæ of individuals belonging to this order. Several attempts were made to rear them to adults but with no good results. The difficulty is to keep the *Sceliphron* living in confinement for a sufficiently long time to enable the parasites to emerge. The wasp dies soon and the parasite, failing to get the requisite amount of moisture from the dead body, follows suit.

Economic.—An insect may be :—

I. Useful.
II. Beneficial.
III. Injurious.

I. It is useful if it produces a thing which is of some economic value ; *e.g.*, Silkworms, Lac Insects, etc.

II. It is beneficial if it destroys our insect enemies, *e.g.*, Parasites, Predaceous insects, etc.

III. It is injurious if it destroys things or insects useful or beneficial to us, *e.g.*—(*a*) Caterpillars damaging cultivated crops ; (*b*) Caterpillars of Eublemma which feed on *Tachardia lacca*, etc.

Let us examine *Sceliphron madraspatanum* to ascertain to which of the above noted three classes it belongs. Does it produce anything which is of any economic utility ? No ; it is, therefore, not a useful insect. What does it destroy ? Spiders. Are spiders our friends or enemies ? I do not pretend to know much or anything about Arachnids. It is, therefore, a very difficult task for me to definitely put down whether the spiders found in the cell of *Sceliphron madraspatanum* are beneficial or injurious to us from an economic standpoint. Casual observations and daily experience tell us that spiders are generally predaceous on insects. On the one hand, we find the common flies, which are a nuisance in our houses during hot weather, and small moths, caterpillars, which damage our crops considerably, entangled in the spiders' webs ; on the other hand, we witness small Hymenoptera and Tachinid parasites struggling for life in the clutches of spiders. In one case we find our enemies destroyed, in the other our friends. It is, therefore, a still more difficult

question to decide whether spiders do greater good by lessening the number of flies and other insects injurious to us, or are productive of greater harm by killing our friends. On a satisfactory answer to this question depends the solution of the main problem. If it is found that spiders do us greater harm than good, the *Sceliphron* is decidedly then a beneficial wasp. But one, who is well conversant with the habits of spiders, can alone opine on this matter definitely and reliably.

What commonsense tells us is that big predaceous beetles, Reduviid bugs, wasps, parasites and dragon flies, etc., are never seen in a spider web, for their weight alone in some cases is sufficient to ruin the whole elaborate construction. It is, therefore, as a rule, only small insects which fall a prey to these spiders. Amongst them may be counted, moths, minute Hymenoptera, Diptera, etc. Of these, moths are generally injurious, Hymenoptera generally beneficial, Diptera both beneficial and injurious. Again, parasites are never so abundant as other insects; consequently out of the insects found in spider-webs a comparatively very much larger number should be of insects other than parasites; and daily experience confirms this conclusion. Generally speaking, therefore, spiders kill insects which are injurious to us, and are thus 'beneficial.' *Sceliphron* wasps which store spiders in their nests are, therefore, 'Injurious insects.'

General.—A strange belief is current in the Punjab regarding this wasp. People there think that it possesses the miraculous power of imparting its shape and colour to other 'insects.' Ignorance of Entomology justifies them in their belief. They say, what they occasionally see. They notice a *yellow and black wasp* bringing spiders and storing them up in mud cells which are closed afterwards. After the lapse of a month or so, they find more than one yellow and black wasp emerging out of the same mud nest. They do not know exactly what happens inside the cells. They only think that spiders having passed some weeks in confinement in the mud nest undergo a complete change in form and colour, under the influence of the wasp.

I cannot help quoting from my note-book one observation which is not very complimentary to this intellectual wasp.

"I was once watching a *Sceliphron madraspatanum* constructing a nest against a window. One cell was completed and another started by its side; spiders were stored in it and the final plug to close the top opening was put in. The wasp then commenced putting mud pellets on the cells; during her absence I scraped off the two cells. The wasp returned as usual with mud and placed it on the traces of the cells left behind on the window. The wasp continued throwing mud pellets with the usual earnestness till the portion once occupied by the cells was completely covered over with mud.

Did the *Sceliphron's* eyes deceive her or does she blindly follow a 'set routine' from the raising of the cell to the throwing of the mud pellets, I cannot venture to guess? However, it is an observation worth recording."

On 2nd April 1911, I removed from a wall a nest of this wasp, all the cells of which contained hibernating larvæ, excepting one which had freshly paralysed spiders stored in it. This cell was placed at right angles to the remaining ones and was evidently constructed only a few days prior to my removing the nest. On the spider at the bottom of the cell was found a two days' old larva. Naturally the colour of the mud used in the construction of both, the nest and the cell, could not be the same. That of the former was lighter than that of the latter. But the difference in colour was noticeable only from the inside, *i.e.*, the side which was against the wall. Externally the cell appeared to be a part of the same nest, and no one could imagine that it was added some months after the nest was constructed, for the wasp had put mud pellets not only on her own cell but also on the nest. Different conclusions can be drawn from this incidence according as we may view the wasp's action. We may take her to be endowed with "wonderful instinct" thinking that she took special care to blend her cell with the nest so skilfully as to deceive human eyes, or we may call her a stupid wasp considering that she simply wasted her energy in throwing mud pellets on a

nest which was after all not her own, and to which she had added only a single cell.

Empty cells in the nest of *Sceliphron madraspatanum* have been observed on several occasions to be inhabited by the larvæ of *Sceliphron violaceum*, *Megachile lanata*, and *Odynerus punctum*.

I can fully endorse Horne's observation that no bird attacks this wasp ; stomachs of hundreds of birds were opened and examined in our laboratory, but the body of this wasp was never found in any of them.

Sceliphron coromandelicum (Lepel).

Sceliphron coromandelicum is larger in size than *Sceliphron madraspatanum* and consequently the mud cells of the former are longer and wider than those of the latter. The egg, larva, and pupa of *coromandelicum* are also proportionately larger in size than those of *madraspatanum*, and even the spiders stored by the former in its cells are bigger in size than those found in the cells of the latter. The following measurements will clearly show this point :—

	S. madraspatanum.	S. coromandelicum.
Length of cell externally	27 to 30 mm.	30 to 33 mm.
Width across	6 mm.	9 mm.
Egg	about 3 mm. long	about 3·1 to 4 mm. long.
Full-grown larva	about 14 mm.	about 18 to 19 mm.
Pupa	13 to 14 mm.	about 17 to 18 mm.

Sites selected by this species for nest-making are usually doors, windows, walls, and hollows of trees. It appears that this wasp takes great pains in selecting a really good and well protected site for this purpose. I have seen scores of these nests inside hollows of trees but never come across a single instance in which the nest was built in a place exposed to rain or moisture. With a peculiar interest I used to watch such trees as had in them several sheltered recesses and was always struck with admiration to notice all the recesses watered, after a heavy shower of rain, excepting those occupied by the nests of this wasp. A single nest may contain from one to eighteen or more cells, and when finished it is completely

covered over with mud. Sceliphron's throwing mud pellets on a nest is always a sure indication of the fact that no more cells are to be added.

The life-history of this wasp is exactly similar to that of *Sceliphron madraspatanum*, and need not be repeated here *in extenso*. Briefly it is as follows :—

The egg is laid on the first spider brought into the cell. The egg is 3·4 to 4 mm. long and invariably hatches on the following day. The young larva on consuming the spider on which it finds itself attacks the next spider above it, and this is continued till all the spiders stored by the mother wasp are exhausted in a week's time. The larva is full-grown then and measures about 18 to 19 mm. It spins a cocoon within which it rests from 3 to 5 days prior to pupation. On the 12th day after pupation the thin pellicle covering the pupa is cast and the wasp emerges. The period from egg to perfect wasp is about 4 weeks.

Enemies.—From the cells of this species have been bred the following parasites :—

(*i*) Chrysid wasps.

(1) *Chrysis fuscipennis.*

(2) *Chrysis sp.*

(*ii*) Tachinid flies.

(Species undetermined.)

(*iii*) Strepsiptera.

It is not necessary to repeat here what has already been said respecting the above-mentioned parasites under *Sceliphron madraspatanum*. But one interesting point is worth recording.

On 9th August 1908 I scraped off a *coromandelicum* nest, consisting of four cells. It was found on examination that from two of the cells perfect wasps had already flown out, and that the remaining two were still closed. The "lids" of these cells were removed, and big, partly dried spiders were seen inside, a fact which assured

nest which was after all not her own, and to which she had added only a single cell.

Empty cells in the nest of *Sceliphron madraspatanum* have been observed on several occasions to be inhabited by the larvæ of *Sceliphron violaceum*, *Megachile lanata*, and *Odynerus punctum*.

I can fully endorse Horne's observation that no bird attacks this wasp ; stomachs of hundreds of birds were opened and examined in our laboratory, but the body of this wasp was never found in any of them.

Sceliphron coromandelicum (Lepel).

Sceliphron coromandelicum is larger in size than *Sceliphron madraspatanum* and consequently the mud cells of the former are longer and wider than those of the latter. The egg, larva, and pupa of *coromandelicum* are also proportionately larger in size than those of *madraspatanum*, and even the spiders stored by the former in its cells are bigger in size than those found in the cells of the latter. The following measurements will clearly show this point :—

	S. madraspatanum.	S. coromandelicum.
Length of cell externally ...	... 27 to 30 mm.	30 to 33 mm.
Width across	... 6 mm.	9 mm.
Egg	about 3 mm. long	about 3·4 to 4 mm. long.
Full-grown larva	about 14 mm.	about 18 to 19 mm.
Pupa	... 13 to 14 mm.	about 17 to 18 mm.

Sites selected by this species for nest-making are usually doors, windows, walls, and hollows of trees. It appears that this wasp takes great pains in selecting a really good and well protected site for this purpose. I have seen scores of these nests inside hollows of trees but never come across a single instance in which the nest was built in a place exposed to rain or moisture. With a peculiar interest I used to watch such trees as had in them several sheltered recesses and was always struck with admiration to notice all the recesses watered, after a heavy shower of rain, excepting those occupied by the nests of this wasp. A single nest may contain from one to eighteen or more cells, and when finished it is completely

covered over with mud. Sceliphron's throwing mud pellets on a nest is always a sure indication of the fact that no more cells are to be added.

The life-history of this wasp is exactly similar to that of *Sceliphron madraspatanum*, and need not be repeated here *in extenso*. Briefly it is as follows :—

The egg is laid on the first spider brought into the cell. The egg is 3·4 to 4 mm. long and invariably hatches on the following day. The young larva on consuming the spider on which it finds itself attacks the next spider above it, and this is continued till all the spiders stored by the mother wasp are exhausted in a week's time. The larva is full-grown then and measures about 18 to 19 mm. It spins a cocoon within which it rests from 3 to 5 days prior to pupation. On the 12th day after pupation the thin pellicle covering the pupa is cast and the wasp emerges. The period from egg to perfect wasp is about 4 weeks.

Enemies.—From the cells of this species have been bred the following parasites :—

(*i*) Chrysid wasps.

(1) *Chrysis fuscipennis.*

(2) *Chrysis sp.*

(*ii*) Tachinid flies.

(Species undetermined.)

(*iii*) Strepsiptera.

It is not necessary to repeat here what has already been said respecting the above-mentioned parasites under *Sceliphron madraspatanum*. But one interesting point is worth recording.

On 9th August 1908 I scraped off a *coromandelicum* nest, consisting of four cells. It was found on examination that from two of the cells perfect wasps had already flown out, and that the remaining two were still closed. The "lids" of these cells were removed, and big, partly dried spiders were seen inside, a fact which assured

me of the presence of some parasites in them. I found at the bottom of each cell, covered by a brown cocoon, a full-grown Chrysid larva. In due course of time from one cell emerged (on 20th August 1908), a Chrysid wasp, but the pupa in the other did not even reach the stage of changing colour. Seven days afterwards (on 27th August 1908) a Chalcid (*Prelampus sp. ?*) came out, piercing the cocoon from above. On examining the parasitised pupa of the Chrysid wasp I found a thin brownish yellow cocoon of the Chalcid attached to the median segment of the wasp pupa. This is an example of the phenomenon known as "Hyperparasitism."

Again, in October 1908, I took a large nest of this species consisting of 12 cells from a hollow in an old tree. Almost all the cells were found opened, the perfect wasps had long emerged; still there were a few cells closed. It seemed evident either that there were parasites inside them or that something had gone wrong with the larvæ or pupæ inside. I opened these cells one after another and found in some dried, in others rotten larvæ or pupæ, but from one I obtained a green *Chalcid* parasite (dried up, of course), similar to one I had already reared from the cells of this species (on 27th August 1908). This parasite bears a striking resemblance to a Chrysid wasp and can only be distinguished from it after a close and careful examination.

The life history of the Tachinid parasites has been dealt with previously, but it is an interesting point how the flies emerge from the clay cells of this wasp. Tachinid flies are not provided with strong mandibles of a wasp to cut a passage through the hard walls of a mud cell. Consequently, the emergence of these flies from clay cells was a question worth studying. I made several observations on this subject, which I need not detail here at any length. I simply note down the conclusions arrived at.

As described elsewhere (under *S. madraspatanum*) Tachinid maggots taper towards the head end. This end is naturally very sharp. When these maggots are three days old, they display a voracious appetite and in search of food knock about inside clay cells (or glass crucibles when taken out of clay cells for observa-

tion sake), thrusting the tapering sharp end into the walls. These gentle but persistent strokes of the tapering end work like a drill, and in the case of the common wall of the two adjoining cells, one or two holes may be bored through.

Next, consider the size and position of these holes. (1) Suppose the holes are small (smaller compared to the rotundity of the maggots) and bored by nearly full-grown maggots, rather high up in a cell ; the maggots in such a case cannot get into the next cell. They will pupate, therefore, in their own cell, and, in due course, flies will emerge. If the adjoining cell be empty, as generally is the case (the perfect wasp having flown out), the Tachinid flies will get into it through the 'communicating door' (*i.e.*, holes bored in the common wall in the maggot stage) and escape through the passage cut open by the wasp. If not empty, it must* contain a wasp pupa in a very advanced stage, nearly filling the whole of the cell. Flies will in that case remain in their own cell till the time the perfect wasp emerges, leaving a free passage behind for the flies to get out. In case the flies are required to wait longer than a couple of days, they invariably perish inside their cells ; and it is due to this fact, therefore, that we sometimes find dead and dried specimens of these flies on breaking up some mud nests. (2) Suppose the holes made are so big and so situated as to admit of the maggots sliding through into the adjoining cell. Maggots will decidedly in such a case get into the next cell and eat up the wasp larva or pupa. Should it not satiate them they would work their way into the next adjoining cell till their hunger is appeased. Their emergence will, of course, depend on the circumstances detailed above.†

Economic.—I have nothing more to add to what has been said in this connection under *Sceliphron madraspatanum.* The same remarks apply here also.

General.—1. Empty nests of this wasp have been found to be inhabited by *Pompilid* wasps—*Pseudagenia* sp. Observations on this subject appear under *Pseudagenia.*

* Because these Tachinids and Sceliphrons take nearly the same time to develop from the egg to imago.

† In this connection see also p. 238.

2. A finished nest of this species is very much like that of *Sceliphron madraspatanum*, excepting that the nest of the former is bigger in size than that of the latter. By a 'finished nest' I mean a nest to which no more cells are to be added, and one which is completely covered over with mud.

Nests of these two species in the unfinished state are quite distinct and can be distinguished from each other without much difficulty. Beautiful ridges are seen across the cells of both the species. These run more or less obliquely (only slightly curved downwards) in the case of *coromandelicum*, but the curve runs into an angle near the middle in the case of *madraspatanum* (Plate XIII, Figs. 7 & 8).*

Some time in October 1908, I collected beautiful clay cells (all arranged in one line), which were decidedly of some *Sceliphron* species; with the aid of the above-mentioned test, I could put them down as those of *Sceliphron coromandelicum*. In the previous April I had collected a nest, containing 18 cells, all arranged in one line, but unfortunately all the cells were empty; I therefore could not find out definitely what species had constructed the cells. The cells collected in October were exactly similar in general shape and structure to those found in April, and since the former were yet inhabited there was every hope of knowing the species on the emergence of the perfect wasps from these cells. I had to wait till 2nd April 1909, when *Sceliphron coromandelicum* began to emerge one by one from the cells. Now *Sceliphron coromandelicum* never places all her cells in one line. No doubt at first she makes three, four or five cells in a line, and then two, three or four cells (as the case may be), are placed over them, and then another layer of one or two cells succeeds till at last the whole construction is covered over with mud; but as many as eighteen cells are never placed in one line; as found in the case of the nest obtained in April 1908. *Coromandelicum* commences nest-making in April each year, the empty nest of April 1908, therefore must have been constructed in the middle of the previous October, when the nest-making for the hibernating brood is started.

* NOTE.—This holds good when the cells are viewed from the front and not from the side.

Thus I got two nests, agreeing with each other in general shape, structure and the arrangement of cells, and which were both constructed in the same month of different years. From these facts it may be concluded that the cells of *Sceliphron coromandelicum*, built late in autumn, are *sometimes* (not always) placed in the above-mentioned way, *i.e.*, all in one line.

I cannot assert this point with any force till I secure more such nests, either late in autumn or any time from winter to the advent of the ensuing spring.

Sceliphron bilineatum (Smith).

This wasp, until 1908, was recorded from Western India alone, but in that year was obtained from Pusa, in the North-East part of India.

In general appearance and colour it looks very much like the common mud-dauber, *Sceliphron madraspatanum*, and especially when in flight it is not easy to distinguish one from the other.

S. bilineatum has more yellow colour on the body than *madraspatanum*. The sides of the median segment and a conspicuous spot on the segment succeeding the petiole are yellow in the former, but black in the latter.

Both construct mud cells and store spiders in them, but in the nest-making habit they differ widely. The cell of *madraspatanum* is semi-cylindrical, while that of *bilineatum* is long, oval, being broadest in the middle (Fig. 10). In the case of the former it is entirely fixed from top to bottom against a wall, while in that of the latter only the bottom is fixed, and the rest of it raised at an acute angle. The former constructs cells in juxtaposition and completely covers them all afterwards with mud; the latter erects

FIG. 10—SCELIPHRON BILINEATUM CELL. (I. T. L.)

them singly and finishes them by filling up furrows between the ridges on the surface of the cells with mud and smoothing the whole cell from outside as a mason does a wall with a trowel (Fig. 10*a*).

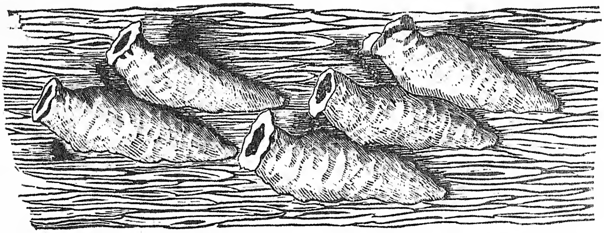


FIG. 10*a*.—SCELIPHRON BILINEATUM CELLS ON THE TOP OF A BOOKSHELF.

The full-grown larvæ of both spin brown cocoons in which they pupate, but the cocoon of *bilineatum* is lighter in colour and more delicate than that of *madraspatanum.*

With the few exceptions mentioned above *Sceliphron bilineatum* behaves in other respects exactly in the same way as *S. madraspatanum.*

The egg is laid on the first spider brought into a cell; the larva on hatching commences to feed on the spiders stored by the mother wasp; when full-grown it spins a cocoon in which it pupates. With the discharge of excrement (in the cocoon) the larva loses its active life and then follows a period of rest. The larval skin is cast off and a whitish pale pupa having all the limbs of the perfect wasp appears. Gradual changes in the colouration of the pupa then set in, till the colour of the perfect wasp is assumed. The thin pellicle covering the pupa is shed in due course of time, and the perfect wasp (Fig. 11) emerges through an opening made at the top of the cell.

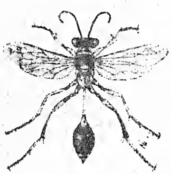


FIG. 11.—SCELIPHRON BILINEATUM. (I. I. L.)

The life cycle of this species also is completed in about the same time, *i.e.*, four weeks. Another point of interest in this species which we find in *madraspatanum* and *coro-*

mandelicum also, is that the mother wasp always constructs a cell, the capacity of which is just sufficient to hold that number of spiders which is necessary for the full growth of the larva; its length is always a little more than the length of the cocoon to be spun by the full-grown larva. The full-grown larva, in turn, spins a cocoon which is just a little longer than the would-be mature pupa, plus the length of excrement to be deposited at the bottom of the cocoon. The undernoted measurements will clear this point—

Length of a cell is about	24 mm.
" " cocoon is about	20 mm.
" " pupa is about	15 mm.
" " excrement is about	3 mm.

Enemies.—Two parasites have been reared from the cells of this species.

(*i*). Chrysid (*Chrysis* sp.).

(*ii*). Tachinid flies (Species undetermined).

I have nothing more to add here to what has already been said concerning the above parasites under *Sceliphron madraspatanum* and *S. coromandelicum*; excepting the following observation which seems necessary.

Since the cells of this species are constructed singly, and there is no superfluous quantity of mud thrown over them to disguise their shape, the walls of these cells are very thin. Consequently the holes bored by the full-grown Tachinid maggots into the sides of the cells serve as so many openings for the flies to escape through.

Sceliphron violaceum (Fabr.).

Wasps of this species are very pretty, and can be readily distinguished from other species belonging to this genus by their conspicuous cobalt-blue colour.

The female does not construct mud cells as do other species of this genus, but always takes advantage of ready-made holes in

which she stores spiders and lays eggs. These holes are subsequently closed with not exactly mud, but mud mixed with mortar and lime.

In all odd and queer holes, such as in walls, doors, windows, bedsteads, bamboos, barrels of rifles, etc., nests of this species are to be seen. In short, wherever she finds an empty convenient hole she utilizes that for her nest. Once I found a cell in the central cylindrical aperture of a common wooden bobbin. At another time from a long deserted nest of *Sceliphron madraspatanum* I got two pupæ of this wasp. I was puzzled a little in the beginning, but in the queer nesting habit of this wasp (of occupying empty holes) I found the solution. A few days later I actually saw a *Sceliphron violaceum* entering into an empty cell in the nest of *Sceliphron madraspatanum*. But the question of *Sceliphron violaceum* occupying empty cells in *Sceliphron madraspatanum* nest was definitely decided, when I observed that :—

* "From a *Sceliphron madraspatanum* nest which was long under my observation, all the wasps had emerged, and as this nest consisted of three cells there were three neat circular holes visible on the top of the nest. On my going over one day to the place where the nest was situated I was astonished to find only two holes left ; the third one was closed. I removed just a little mud (rather plaster of clay, mortar and lime) from that corner of the nest where the third opened cell was located. From below came to view the top of a dark brown cocoon. I scraped off the nest from the wall and gently opened up this cell. To my great satisfaction I found the lower part of an empty *madraspatanum* cocoon at the bottom of the cell and just above it a dark brown cocoon enclosing a *violaceum* full-grown larva."†

From this cocoon emerged a *Sceliphron violaceum* on 10th September 1908.

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* This is quoted *verbatim* from my observation book.

† The cocoon spun by a full-grown *violaceum* larva is smaller in size than that of the *madraspatanum* larva.

Horne records some observations regarding this species under the name of *Pelopœus bengalensis* in the Trans. Zool. Society VII (1870), p. 163. The sketch (Pl. XXI, Fig. 2) which accompanies his account appears to me to be the nest of *Sceliphron madraspatanum* rather than that of this species. He says that "the cells are placed side by side in great numbers, say twelve or fourteen, and so well covered over with mud as to be almost unobservable"; but at Pusa I have never seen this wasp constructing an entire separate nest. All that she does in the way of construction is the putting on of 'caps' over deserted or empty cells of other mud-nest-making wasps which are appropriated by her. It is very unlikely that this wasp should have an altogether different nesting habit outside Pusa. There are only two possibilities: either that Horne collected an appropriated nest of *Sceliphron madraspatanum* and on the emergence of his *bengalensis* from the cells mistook the nest as belonging to the latter species or that the wasp has reformed and learnt to be more economical since the time of Horne's observations over 40 years ago.

This habit in some insects of appropriating empty or deserted nests or cells of other wasps always leads to faulty conclusions. In the first place, nests are associated with insects which never constructed them. Secondly, when the nests are known to belong to a species other than the one which has emerged from the cells, the latter is by mistake considered to be parasitic on the former. I remember an instance of this sort of mistake. A student in our laboratory once brought to me examples of *Megachile lanata* (F.), which he asserted were parasitic on *Eumenes conica* (F.), solely on the ground that he reared them from the cells of the latter. Needless to say that it was a clear case of appropriation of empty cells.

Besides *Sceliphron violaceum* the following have been reared by me from nests which originally belonged to other wasps :—

Insects bred.	Nests from which bred.
1. *Pseudagenia clypeata*, Bingh.	*Sceliphron coromandelicum* (F).
2. *Pseudagenia* sp. (unidentified, probably new) ...	,, *madraspatanum* (F).
3. *Megachile lanata* (F)	*Eumenes conica* (F).
4. *Odynerus punctum*	*Sceliphron madraspatanum* (F).

It may be pointed out here that while *Sceliphron violaceum* (F) simply 'caps' the cells, the *Pseudagenia* spp. and *Megachile* (referred to above) make their own cells inside the cavities. The *Pseudagenia* sp. had made four cells inside a single cell of *Sceliphron madraspatanum* (F).

GENUS SPHEX.

Sphex lobatus, F.

This is one of the commonest wasps found at Pusa. Its large size, charming metallic green colour with golden rosy tints, and graceful flight at once distinguish it from other wasps.

The female wasp (Fig. 12) is generally seen digging up cricket-burrows in fields and meadows from April to August. The cricket is driven out of the burrow, caught, stung and paralysed. It is then removed by the wasp to her nest, but what follows has not been observed. Probably an egg is laid, and the larva feeds on it. When the whole supply of crickets is consumed, the larva pupates and in due course of time the perfect wasp emerges.

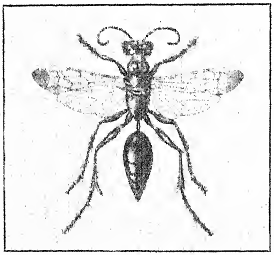


FIG. 12.—SPHEX LOBATUS. (I. I. L.)

Economic.—This wasp preys upon one particular species of Gryllid—*Brachytrypes achatinus*, Stoll., which is a pest of Lucerne, Indigo and Tobacco in Bihar. It is therefore certainly a beneficial insect inasmuch as it checks the spread of an injurious one.

In Bengal ladies make a charming use of the delightfully brilliant skin of this wasp. Circular discs neatly cut out of its body are fixed in the centre of the forehead by way of ornamental decoration. The wasp is known there by the popular name of "Kanch poka, or the Golden Insect."

Ampulex compressa. (Fabr). (Fig. 13).

The habits of this wasp have been described in "Indian Insect Life" at pages 207-208. I have nothing more to add save that these wasps sometimes frequent our houses in search of the big household cockroach,—*Periplaneta americana.* On several occasions I have seen this cockroach being dragged up a wall by this little active wasp, not in the way a paralysed cricket is taken by *Notogonia subtessellata* (Sm.) but like a truant moving schoolwards with unwilling steps when dragged by superior force. The cricket makes no effort to move and is simply dragged like a mere corpse, but the cockroach walks on its own legs. It follows from this that the latter is not so completely paralysed as the former, or in other words, the cockroach is not stung in all the nerve centres; consequently, movement of limbs, though a little restrained, is still allowed it. I should think this action of the wasp deliberate; and it displays very well her intelligence. She realizes fully, it appears, the difficulty she will have to encounter in removing such a heavy load from ground to the top of a house if the cockroach were deprived of its locomotion. Now she simply pulls at an antenna and the big cockroach moves on heavily, although much against its inclination. This concession (partial movements of limbs) so dangerous afterwards to the wasp egg and young larva, is not permitted longer than necessary. The wasp takes care to bite off all such limbs as legs, wings, etc., before laying up the cockroach in the nest as provision for the young.

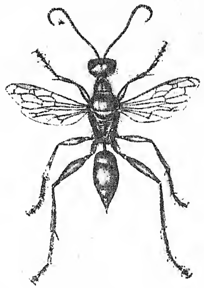


FIG. 13.—AMPULEX COMPRESSA. (I. I. L.)

Economic.—Cockroaches chiefly live on dead and decaying animal and vegetable matter, and as such are good scavengers, but when found in houses in large numbers they are a regular nuisance. *Ampulex compressa* in checking their spread is decidedly beneficial.

Stigmus congruus, Walk.,

and

Stigmus niger, Motsh.

These tiny black wasps have been observed carrying away Aphides, which they probably store in their nest as provisions for the young. An enormous quantity of sap is extracted by Aphides from plants which they infest, and which, consequently, look unhealthy and wither away prematurely. These wasps prove a natural check on them, and are, therefore, beneficial. One of my flowering plants was once badly covered with a yellow species of Aphis, but lady-bird beetles and these wasps appeared in time to clear it of the pest and thus saved it from the inevitable decay.

Bembex orientalis, Handl.

Bembex orientalis, Handl., is the commonest wasp of this genus found at Pusa. It nests in soft sandy soil not far from river banks. The entrance to a nest is more or less a transverse slit. In May 1909 I dug up several nests but from none of these did I obtain any egg, larva or pupa, of the wasp. Perfect wasps, however, were found in them. In the yellow colour of these wasps there was noticed a lovely freshness, which is so peculiar to things which remain screened from the sun. Exposure to the sun's rays changes or bleaches a colour to some extent. For instance, the body of *Myrmecocystus setipes*, Forel, dug out fresh from a nest underground, is yellowish brown, but the colour of specimens caught flying or running outside a nest, is totally brown and tawny ; yellowishness completely vanishes away on exposure to sun-light. From this it will easily be inferred that *B. orientalis* must have been present in the imago form in the nest long before my digging them up. It will be within the limits of possibilities then to suppose that hibernation in the case of this wasp takes place in the imago stage.

Philanthus pulcherrimus, Smith.

My note on the habit of this wasp has already appeared in "Indian Insect Life" at page 209 and I reproduce it here.

"This wasp is common at Pusa during the months of March and April. It is usually found on flowering plants, on the flowers of which bees are also hovering. This wasp attacks them, stings them, and then flies away with them to the nest. The bee is held by the wasp below the thorax between the legs. Nests of this wasp are in sandy banks, and are in the form of long narrow tunnels. Females are observed bringing bees, generally belonging to the genera '*Halictus*,' '*Ceratina*' and '*Apis*' to their nests and the choice seems restricted to the family *Apidæ*."

Economic.—The mother-bee generally fills a cell with a mixture of pollen and honey. She is furnished therefore with bristly, branched, plumose, and twisted hairs, which facilitate the work of gathering pollen from flowers. When she buries herself in the blossoms, pollen grains stick to the peculiarly modified hair. As the bee flies from one flower to another of the same plant, some of the pollen grains of the former, come in contact and adhere to the stigma of the latter and pollenize it. Similarly while she flies from one plant to another cross-pollination is accomplished. Thus the bee incidentally pollenizes flowers while collecting pollen which she stores in her cells; and as such she is a very beneficial insect in flower and fruit orchards. *Philanthus pulcherrimus* attacking these is decidedly an injurious wasp.

FAMILY EUMENIDÆ.

Genus EUMENES.

Eumenes affinissima, Sauss *Var.*

This wasp is shown on Plate XIII, Fig. 11. Single cells of this species have been collected from the branches of Jhau (*Tamarix sp.*). (Pl. XIII, Figs. 9 and 10). The mud used appears to be very finely kneaded, and the cells are very delicate.

Eumenes esuriens, Fabr.

This wasp is similar in habits to *E. conica.* The female wasp constructs mud nests, consisting of three or four cells, and each cell

is stocked with paralysed caterpillars. The nests are found in various odd places, *e.g.*, corners of houses, against walls, rafters and windows and in bamboos, tree-trunks, etc. On one occasion a rejected circular wick of a table lamp was occupied by this wasp. The shape of a cell is very much like that of *Eumenes conica;* being elliptical in plan, and semi-elliptical in section. The wasp takes about 3 hours to raise the cell and about an equal number of hours to store caterpillars in it. A cell which was started at about 11 A.M. one day, was finished by 2 P.M. the same day; and the caterpillars were stored and the cell plugged by 5 P.M. The time required to stock the cell with caterpillars depends on the abundance or scarcity of caterpillars and the distance from which they have to be fetched. If they are found close at hand and in large numbers the time taken will proportionately be very much less than when they have to be brought in from a long way off and are few in number.

The egg, as in the case of *Eumenes conica*, is suspended by means of a fine thread, inside a cell. It hatches in a couple of days, the young larva feeds on the paralysed caterpillars stored in the cell and grows in size. On the 3rd day it measures 12 mm. by 4 mm. and on the 5th day it is full-grown when it commences to line the inside of the cell with silk threads. On the 6th day excreta are discharged and the larva measures 15 mm. by 5 mm. and is yellow in colour. On the 8th day it pupates. In the freshly formed pupa the abdomen is joined on to the thorax broadly, and the segment (petiole) joining these two parts of the body gets thinner and thinner till it is reduced to its ultimate dimensions. The petiole in this stage is never stretched lengthwise but is kept in an oblique position. The abdomen consequently remains more or less at right angles to the longitudinal axis of the pupa. The length of the pupa measured from head to the base of the 2nd abdominal segment is about 11 mm.

The general colour of the pupa is yellowish white and the wing pads are slightly brownish. A change in the colour of eyes takes place on the beginning of the 3rd day after pupation. On the 7th

day reddishness is suffused all over the body; the mesothorax assumes a brick-red colour, the petiole and the abdominal segments becoming reddish brown. All the sutures on the thorax, a transverse band on the petiole and another on the apical margin of the 2nd abdominal segment turn black. On the 9th day yellow markings on the thorax and abdomen appear prominently, and on the 10th day the thin pellicle covering the pupa is cast and the wasp emerges. On the following day the limbs harden and the wasp cuts a hole in one side of the cell and escapes. Thus from egg to imago this wasp takes about 21 days.

Eumenes conica, Fabr.

The female *conica* constructs mud cells in the corners of houses against walls, wooden furniture, etc. There are generally 6 to 10 cells in a complete nest. The cell is convex from outside, elliptical in plan and semi-elliptical in section. The approximate length of a cell measured along the major axis of the plan is 22 mm. and the breadth along the minor axis 12 mm.

The female *conica* brings a mud pellet and lays it out in a curve on the place where she intends to construct her nest. She goes out and brings more mud which is added on to the first curve. Several times the wasp goes out in this way and returns with mud pellets which are worked into the wall of the cell. When the wall rises to a height of about 6 mm. all round, in a plane at right angles to the one against which the nest is being constructed, a gentle curve is given to the remaining portion of the construction which ends in a small central aperture about 4 mm. in diameter surmounted by a structure which may well be compared to the neck of an Indian water pitcher with a rim. Through the aperture are slid in well developed green caterpillars (generally semi-loopers), which are brought stung and paralysed (but *never dead*), to be laid up as provision for her young. (Note :—The caterpillars are sometimes found to be parasitised.)

The number of these caterpillars in a cell varies; usually it is five, but if the caterpillars are small and not fully developed, their

number may be nine or more; and in case the wasp is scared away, caught or killed before closing the cell, the number of caterpillars stored is much less.

When the egg is laid and the necessary number of caterpillars has been stored in a cell, the pitcher-rim structure is demolished a little and the central aperture is plugged with mud. Another cell is started just above it, the lower side of the second touching the upper side of the first; but in case the nest is located in a corner, the cells overlap each other to some extent. Thus cells are added on one after another, till the required number is reached.

As already remarked *E. conica* may construct 7 to 10 cells in one place if not disturbed, but if, on each return to an unfinished cell, she finds someone closely watching her nest, she quits it, suspecting some mischief and starts a new nest in some other locality. It is partly due to this reason that one generally comes across such nests as have two or three cells closed and the top-most cell with the characteristic pitcher-neck still existing. Sometimes solitary unclosed cells are also found for similar reasons. As a rule, one egg is laid in a cell; only in one case I found three very similar eggs suspended in an unclosed cell. In her egg-laying habit *Eumenes conica* differs from some wasps, as the egg is not laid on the food of the larva, but is suspended by means of a very fine thread from what we may call the roof of the cell. The length of a freshly laid egg is about 3·2 mm. and that of the thread about 1·5 mm. The colour is uniformly yellowish white, but later on only the portion occupied by the embryo retains this colour and the rest of it (near both the ends) becomes colourless. It gradually increases in length to about 4·5 mm. and in shape is long and cylindrical (slightly curved) with ends rounded. The egg stage lasts for about 2 days. The egg splits on one side, and the rent gradually increases downwards till the larva puts forth its head and as much of its body as may enable it to reach the food below. It does not leave the egg-shell so long it can get at the food from its suspended position, and so long as it is too delicate to receive convulsive strokes from the paralysed caterpillars. When freshly hatched the larva measures about 4 or 4·5 mm. long and

1 mm. broad. It is green in the middle, the anterior and posterior ends being colourless. This green colour deepens and then gradually spreads all over till some yellow appears mingled with it, the latter colour predominating eventually. It moults three times prior to its attaining full length.

The following table gives the dates of different moults as observed in the case of two larvæ :—

Hatched	...	... 20th March (night)	22nd March (night).
1st moult	...	... 21st ,,	23rd ,,
2nd ,,	...	... 22nd ,,	24th ,,
3rd ,,	...	.. 23rd ,,	25th ,,
Pupated	...	... 3rd April (at 3 P.M.)	5th April (night).

When, in a week's time, it is full grown, it has the appearance of a yellow mass of flesh tapering towards both ends, and divided into distinctly marked segments. It is about 19 to 20 mm. long and 6 to 9 mm. broad in its widest portion. It has ten small round spiracles on each side of the body.

In the cell the full-grown larva spins a cocoon, inside which it rests for some days before pupating; but if taken out of the cell it hardly spins any cocoon, and, if at all, only a few threads are drawn across the body. The cocoon is of a very thin consistency and is spun quite close to the walls of the cell; practically the cell is lined with silk threads. It serves two purposes (*i*) keeping the pupa enclosed in a soft covering and (*ii*) hardening up the wall. It has been observed that a cell containing a pupa offers greater resistance to breaking than one containing a larva. It may also be noted in this connection that almost all the mud-nest-making wasps appear to add something of the nature of saliva to mud to make it more sticky and hard; for it is comparatively much easier to break a cell made by human hands than one constructed by a wasp, even though the mud used in both the cases be the same.

Excreta are discharged inside the cocoon, and the larva becomes motionless. The colour turns to a delightful yellow and the body is much contracted. After 3 to 5 days' rest, the fifth and sixth segments of the body (reckoned from head end) are narrowed. This announces that the insect is about to enter upon the third

stage (pupal) of its metamorphosis. The larval skin is shed and there appears a wonderful change in the insect. It is no longer a tapering mass of flesh, but has all the limbs of the perfect wasp. Head, eyes, antennæ and its joints, thorax, legs and its joints, and abdomen, in fact, every part of the body comes out distinct and clear except the petiole which is very broad and thick. The abdomen appears to be broadly joined on to the thorax, as in the case of Sessiliventres. The petiole gradually reduces to its normal dimensions by the following day. The colour of the pupa at this stage is light yellow all over, excepting the antennal and tarsal joints which are white or colourless and the rudimentary wings which are brownish. The pupa when fresh measures 12—13·5mm., and increases in size as the petiole gets thinner and longer. Then follows a gradual change in colouration. The eyes exhibit signs of change first; two days after pupation they get a slightly pinkish tinge which deepens on the 3rd day; on the 4th day the eyes get slate-coloured; on the 5th day there is more of darkness and only an obsolescent tinge of bluishness. On the 6th day, eyes are black, though not quite. There is just a reddish tinge all over the body; and there also appear a thick black line behind the eyes, a longitudinal black line traversing half the length of the mesonotum, another transverse stripe on the middle of the 2nd abdominal segment above. The different parts of the thorax come out clear and distinct. On the 7th day after pupation the different segments of the abdomen become separated and lateral pinkish lines appear on them. Excepting antennæ, legs and the ventral side of the abdomen, the whole insect becomes reddish, the sutures between the pro- and meso-thorax, meso-thorax and scutellum become dark. The insect becomes more red day after day till the dull red colour of the perfect wasp appears on the 10th day after pupation. The clypeus, sinus in the eyes and narrow stripes behind them become yellow. Up to this day the wings do not appear developed, and in their place one finds thick pads of skin, covering the meso- and meta-pleuræ. On or about the 12th day the thin pellicle covering the pupa is cast off, and at once the long, longitudinally-folded wings appear. For this day the

wings are kept over the body parallel to it, but on the next day when the wasp gets dry they are spread out almost at right angles to the body. This happens when a larva is taken out of a cell and bred in a cage, but if allowed to complete its metamorphosis inside a cell, the perfect wasp remains inactive for a day and on the following day, when the limbs are hardened, emerges from the cell through a hole cut in the upper side.

Thus the period occupied from egg to imago is four weeks :—

Egg stage about	... 2 days.
Larval stage (including resting stage) ...	... 9 to 14 days.
Pupal stage about	... 12 to 13 days.
TOTAL	... 23 to 29 days.

As mentioned above, sometimes the uppermost cell in a nest is found unclosed with only a couple of caterpillars in it for the larva. The larva on finishing this short supply of caterpillars undergoes metamorphosis just as a full-fed larva would do. Casting off the larval skin and pupal pellicle, gradual changes of colouration in the pupal stage, and the final emergence as a perfect wasp, take place all at regular intervals.* There is, however, a great difference in the size of the perfect wasps which emerge ; the one from a full-fed larva is very much bigger and consequently stronger than the one whose supply was stinted. This points to an important conclusion that difference in the size of various specimens of *E. conica* of the same sex, depends largely on the quantity of nourishment received during their larval stage.

Enemies.—Stilbum cyanurum, Först., *Chrysis fuscipennis*, Br., and *Chrysis orientalis*, Guér., of the family Chrysidæ, two undetermined

* *From my note-book.*—(June 1908).

"Two larvæ of *E. conica*, taken out one from a closed cell, the other from an opened one ; the former is full-fed and well developed, in resting stage ; the latter much smaller in size, resting.

No. 1. Pupated on 23rd June 1908 (night).
Emerged 5th July 1908.
No. 2. Pupated on 25th June 1908 (noon).
Emerged 6th July 1908.

Both are females, No. 1 very much bigger than No. 2."

species of the family Tachinidæ and *Mutilla regia*, Sm., have been bred here from the cells of this wasp. Chrysids pupate inside a tough reddish-brown (sometimes yellowish-brown) cocoon which the full-grown larva spins in a corner of a cell (Plate II, Fig. 12*a*). Tachinid puparia are found loose inside a cell. Sometimes it so happens that both the parasites, Chrysids and Tachinids are found in the same nest; the emergence of Tachinids from a nest is always perplexing, for it cannot be definitely decided whether the flies bred are parasitic on the caterpillars stored in cells, or on the wasp larva or pupa. I am inclined to believe that the maggots which eat up the caterpillars would not spare the wasp larva; however, flies whose maggots have been found to feed purely on wasp larvæ or pupæ, have been ascertained to be quite distinct from those parasitic on the caterpillars. Below I quote a few observations from my note-book which will throw some light on the subject and elucidate some other points too.

8th April 1909.—"Removed a mud nest of *Eumenes conica*, consisting of six cells, from a window in a house (Pl. XIII, Fig. 12). Out of six, two of the cells contained nothing; of the remaining four in two cells were seen Chrysid larvæ, in the 3rd a Tachinid puparium and in the 4th a full-sized pupa of *E. conica*.

"Just above the pupa, and separated from it by the full-grown larva's thin cocoon, was found a Tachinid puparium (a damaged one containing a dried-up fly), and on the pupa itself near its prothorax a tiny Chrysid larva: (Plate XIII, Fig. 13).* Now it was a puzzle; how could the wasp larva advance to the pupal stage when the Tachinid parasite was also in the cell? On what was the Tachinid maggot nourished? Not on the wasp larva, because it was there in the pupal stage. It must have been, therefore, consuming the food-supply of the wasp larva. The mother *conica* might have stored in the cell, as she occasionally does, a parasitised caterpillar, which by mere chance might have got only one parasitic maggot on it. The

* The tiny larva mentioned above as having been found on the prothorax of *E. conica* pupa, pupated on 18th April 1909 inside a tough cocoon in the cell; the *Chrysid* wasp (*Chrysis fuscipennis*) emerged on 2nd May 1909 (Pl. XIII, Fig. 14).

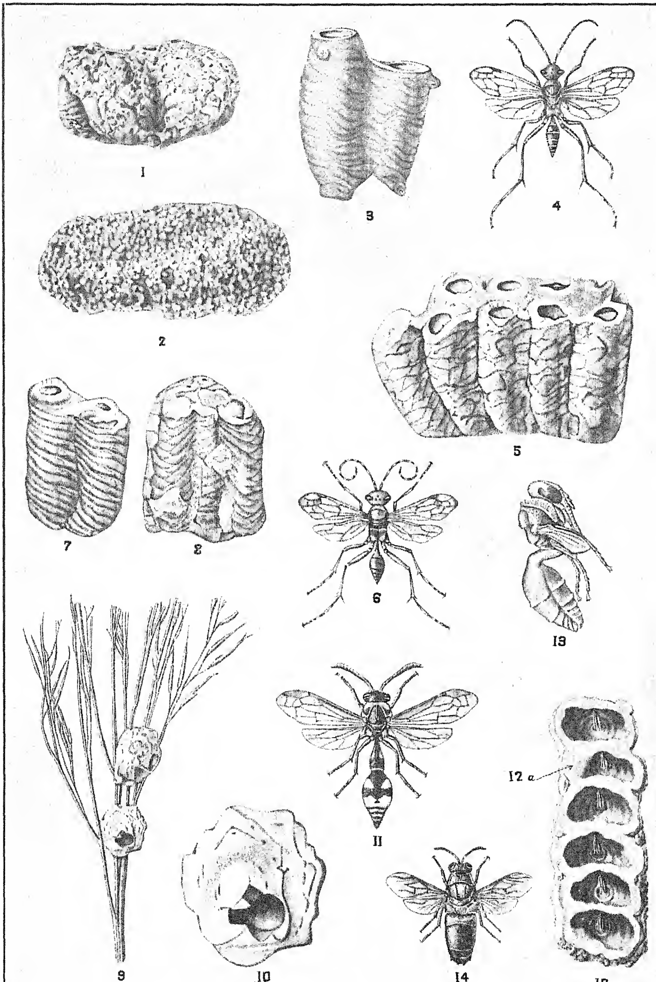
EXPLANATION OF PLATE XIII.

1. Nest of Sceliphron coromandelicum, reduced × $\frac{2}{3}$.
2. ,, ,, inhabited by Pseudagenia clypeata × $\frac{2}{3}$.
3. ,, ,, Pseudagenia blanda × 2.
4. Pseudagenia blanda, male × 2.
5. Nest of a Pseudagenia sp. × 3.
6. Pseudagenia sp., female × 3.
7. Cells from an unfinished nest of Sceliphron coromandelicum. } Natural size.
8. Cells from an unfinished nest of Sceliphron madraspatanum. } Natural size.
9. Cells of Eumenes affinissima, var. on a branch of Tamarix. } Natural size
10. A single cell of the above × 3.
11. Eumenes affinissima var., female × 2.
12. Nest of Eumenes conica as seen from underside × $\frac{2}{3}$.

12a. Cocoon of Chrysis fuscipennis in a corner of a cell.

13. Eumenes conica pupa bearing Chrysis fuscipennis larva on the prothorax × 2.
14. Chrysis fuscipennis × 2.

PLATE XIII.



maggot pupated after consuming the caterpillar and allowed the wasp larva to flourish unmolested. This is on the assumption that the Tachinid maggot requires only one caterpillar for its full growth."

To ascertain definitely how many caterpillars are consumed by a Tachinid maggot before it is full-fed, I broke open several freshly constructed *E. conica* cells; and from one I got a parasitised caterpillar. On this caterpillar were seen five tiny maggots. In the cell there were two more caterpillars besides the parasitised one and the cell was not yet closed. The maggots grew in size gradually; the three caterpillars were consumed clean; their integument alone was left. I put in one more caterpillar which was not paralysed; but only a little crushed, and of nearly the same size as those found in the cell; it was finished; two more were added next, of which one remained uneaten. At this stage the maggots began to pupate. Thus five caterpillars in all were consumed by five maggots, showing that one caterpillar is quite sufficient for one maggot.

It may be noted here that the full-grown maggots measure 7 to 8 mm. in length, and 3 mm. in breadth (in the middle); colour is dirty white; general shape, tapering towards the head end and abruptly truncate towards the tail end. The maggots before pupating contract their body very much, and the puparium is 4·5 mm. long and 2 mm. broad. The colour of a puparium is bright testaceous which gradually turns to dark-brown. The pupal stage lasts for about 12 days. (Note.—The flies that emerged from these puparia have been ascertained to be quite distinct from those reared actually on wasp pupæ).

13*th July* 1909.—"On removing a nest of *Eumenes conica*, I found in one cell Tachinid maggots actually eating into the wasp pupa. The maggots pupated on 15th July 1909 and the flies emerged on the 25th idem." Again, early in October 1909, I removed another nest of this wasp from which I got a pupa damaged in a similar way. Flies which emerged in both these cases were different from those bred on caterpillars. Emergence of the Tachinid flies takes place probably in the same way as described

under *Sceliphron coromandelicum*, for the maggots have been found in this case also to bore their way into adjoining cells in search of food.*

Economic.—As already remarked, *E. conica* stores in her cells paralysed caterpillars which are chiefly semi-loopers. Since it is difficult to identify insects in the caterpillar stage I have not been able to definitely determine the paralysed species. To rear them to moths is rather difficult on account of the poison which the wasp injects into their body. The only way to accurately decide this question is to find out the food-plant of these caterpillars, *i.e.*, to ascertain and see the actual plants from which the caterpillars are carried away by the wasp, and in this direction I have not been successful yet. In one case the caterpillars resembled those of *Cosmophila sabulifera*, Guén., and in another they looked very much like the caterpillars of *Trigonodes hyppasia*, Cram.

Caterpillars are generally herbivorous, and when they increase abnormally on a particular crop, they may do great damage. *Eumenes conica*, exercising some check on these (however little) is decidedly then a beneficial wasp. Cells of this wasp are freely parasitised. Sometimes from a nest of seven or ten cells not a single wasp emerges. Taking five as the average number of cells in a nest and two as the average number of wasps that emerge from each nest (one being male and the other female), we find that 25 caterpillars will be paralysed in the 1st brood ;† an equal number of them in the 2nd brood, and so on. In case there are six broods a year, the total number of caterpillars paralysed by a single wasp (which started nest-making from the middle of April) and its progeny will be $6 \times 25 = 150$. And as these wasps are never numerous at any time of the year what an insignificant fraction

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* But in one instance I found the Tachinid flies emerging by pushing aside a little clay from the nest. This particle of clay did not fall off the nest but was held in position by some threads (probably those with which the full-grown wasp larva had lined the inside of the cell). It opened like a door on hinges. The exit hole was not cut and the clay was removed from that portion of the cell where no extra mud was put by the mother wasp and where evidently the head end of the maggots had worked like a drill. This nest was under my observation during August 1912, when this memoir was in the press.

† Providing the female dies or cannot lay more eggs after completing the first nest.

of the huge number of caterpillars that yearly devastate our crops, is incapacitated by these wasps. Still I would not condemn the good done by them, even though it is so little.

Now consider the other side of the question. Is the wasp capable of doing any harm? If so, to what actual extent? She can sting and perhaps severely, but I have not heard or seen anybody stung by this wasp, nor have I myself had this experience, although I have been so closely and familiarly intimate with her for over three years. *E. conica* no doubt disfigures our furniture, boxes, windows, and neatly white-washed walls by her ugly mud nests, and this is the only fault we can find with her.

General.—The paralysed caterpillars stored by this wasp in her cells have been observed sometimes to pupate successfully, but it is seldom that the pupæ turn to imagines. In one case, however, I remember that a mulberry silkworm, which was removed by the wasp from the silk house, on being rescued from the cell, spun a flimsy cocoon, and the moth emerged in due course.*

Caterpillars belonging to the following families have been obtained from the cells of this wasp.—

1. Caterpillars resembling those of *Anapheis* (*Belenois*) *mesentina*, Cram. Family 'Pieridæ.'
2. ,, ,, (i) *Chloridea obsoleta.* (ii) *Cosmophila sabulifera*, Guén. (iii) *Trigonodes hyppasia*, Cram. } Family Noctuidæ.
3. ,, ,, (i) *Delenia capitata*, Wlk. (ii) *Tephrina disputaria*, Guén. } Family 'Geometridæ.'
4. ,, ,, *Bombyx mori*, Linn. Family 'Bombycidæ.'

In the empty cells of this species *Megachile lanata* has been observed to nest.

Eumenes edwardsii, Sauss.

In October 1908 I got a cylindrical clay cell, with rounded ends, attached singly to a blade of grass. Measurements of the cell were—Height 14 mm.; Diameter of the cylinder about 10 mm. *Eumenes edwardsii*, Sauss., emerged making a hole at the top.

* On 21st March 1912 I removed a few Noctuid caterpillars from a cell. Almost all the caterpillars pupated, but only one turned to moth which proved on examination to be an example of *Plecoptera reflexa*, Guén.

Genus Rhynchium.

Four species of this genus are found at Pusa, *R. brunneum*, F., *R. nitidulum*, F., *R. metallicum*, Sauss., and *R. bengalense*, Sauss. All these wasps stock their nests with paralysed caterpillars and as such are 'Beneficial Insects.' The last named species is found to be infested with *Strepsiptera.*

Rhynchium brunneum, Fabr.

This wasp also, like many others, takes advantage of ready-made holes in which she stores caterpillars as provision for her larvæ. In each cell there may be a dozen of these caterpillars. This wasp is found at Pusa from April to October, but becomes abundant during August and September.

Once (14th August 1908) I observed this wasp entering a hollow in a dried piece of bamboo. She remained inside it for a few minutes and flew out again. She returned after 10 minutes with a caterpillar. She entered the hollow and I thrust in a bent wire behind her. The wasp rushed out buzzing angrily round my head and finally went away. During her absence I managed to remove a couple of caterpillars out of her nest. She returned again, but this time without a caterpillar. (She went out it appears to select a suitable site to shift her nest to). She sat just outside the nest, and then very cautiously entered it. She came out with two or three caterpillars which she carried to another bamboo with a similar hollow in it. Thus all the caterpillars were removed to a new place on such a slight provocation. The caterpillars were of the description given below :—

General shape—Slender, long (17 mm.) cylindrical with the usual five pairs of suckerfeet. Half the body towards the head end in almost all the specimens is yellow with an obsolescent tinge of green above, and the remaining half green. Head light brown with a few pale hairs chiefly on the sides. Prothorax yellowish-brown with black marks posteriorly arranged in a semi-circle. The following two segments have two central oval black marks, each with two black dots inside from which springs a single hair. There are

two more oval marks just behind these, but without central dots; and, lastly, two oval marks on each side with one central black dot bearing a hair. The remaining segments are uniformly marked. Each of them has five marks arranged in two lines, three in one and two in the other.

1*st line.*—Three marks, two black circular rings, one on each side of a central black oval mark, which is bisected by a faint dark longitudinal line. Each half has a black dot in it bearing a single hair. Similarly the side rings have one dot each, with one hair. The central mark is longer than the side ones.

2*nd line*—Two black oval marks and a black spot in each bearing a single hair.

On each side of the body there are 9 black round spiracles. Identified as caterpillars of *Marasmia trapezalis*, Guer.

Economic.—This wasp is decidedly a beneficial insect. It exercises some influence in keeping down the caterpillars of the above-named Pyralid, which is one of the pests of Maize.

Rhynchium nitidulum, Fabr.

This wasp constructs long oval clay cells which are coated with a black gummy substance obtained from certain trees, such as Pipal (*Ficus religiosa*), Babul (*Acacia arabica*), etc. A single nest may contain in some cases up to 25 cells (Fig. 14), but 5 to 10 is the usual number. The nest may be stuck against the ceiling of a house, or it may be inside a hollow of a tree. It is

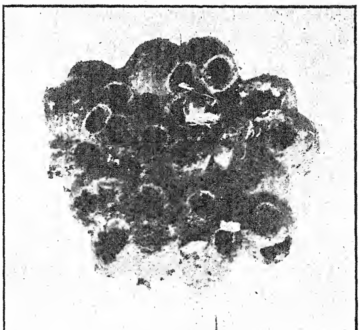


FIG. 14. NEST OF RHYNCHIUM NITIDULUM. (FROM A PHOTOGRAPH.)

never attached by a narrow stalk (as in the case of *Polistes hebræus*, etc.), but the bottom of a couple of cells is firmly adherent to the surface against which a nest is constructed.

The wasp takes nearly half a day to construct a cell and the remaining half of the day is spent in coating it from outside with gum. Paralysed caterpillars are then stored up, and this work may occupy the wasp for 3 to 6 hours. The cell is then closed, and after 30 to 33 days the wasp emerges from it. From 3 cells which were kept under observation, the wasps emerged on the following dates :—

No.	Cell closed on		Wasp emerged on
1.	25th September 1910	... ...	25th October 1910.
2.	29th ,, ,,	... ...	30th ,, ,,
3.	3rd October ,,	... ...	5th November ,,

Chalcid parasites have been reared from the cells of this wasp.

Rhynchium metallicum, Sauss.

This wasp has been observed carrying away Tineid (*Senon latiore*) caterpillars from a plant locally known as "Chakaur" (*Cassia tora*). The caterpillars have the habit of folding up four or five top-shoot leaves together. The wasp knows such leaves to contain her prey ; she comes to the plant directly and settles down on the folded top-shoots. An opening is cut from below, the mandibles are thrust in, and the caterpillar is ousted from its hiding place. At once the wasp pounces on it, stings and flies away with it.

FAMILY APIDÆ.

Ceratina viridissima, Dall. Torr.

This is a beautiful bee of a charming green colour, with metallic blue or golden shades. It is sometimes confused with *Chrysid* wasps from which it can be readily distinguished by the forewing venation. The *Ceratina* has three cubital cells, while the *Chrysid* has none (rarely one).

It nests in hollow reeds and thatch, and excavates tunnels in dried pithy branches of trees. These tunnels and hollows are made

by the female bee in an exquisite way ; the inside of the nest is turned perfectly smooth. A file and sand paper would not finish it smoother. The fine particles of saw-dust are not scattered to the winds, but are compressed and utilised as partitioning walls between the different cells of a nest. In a nest there may be about 5 cells and each cell is about 8 mm. in length ; in shape it is a perfect cylinder. Each cell is provisioned with a little bee-bread which is pollen mixed with honey. On this an egg is laid.

I have ascertained that an egg after it has been laid by the bee increases in length from about 2 mm. to about 3 mm. It is long, a little curved, semi-transparent and very smooth. The thin pellicle constituting the egg shell bursts at one end and the larva pushes its head out. Shortly afterwards the smooth body gets a little wrinkled. As the thin pellicle simply rolls over the larva remains in exactly the same position as the egg, only the wrinkled body tells us that the insect has advanced to the second stage of its development.

The larva on hatching begins to feed on the bee-bread. When freshly hatched it measures a little more than 3 mm. Head is distinct and shiny white. Body is longitudinally margined and transversely ridged. Six spiracles are visible on each side. Larva when half developed is dirty white and yellowish in colour ; in the middle above slightly brownish, towards the tail-end black. Medially a faint dark line, extending from head to the apex of abdomen is visible below the integument.

Development of the larva is slow and when it is full-grown it is about 8 mm. long. Head and thorax creamy white, semi-transparent, the rest of the body yellow (colour of bee-bread) ; the posterior segments are distinct. Just a line to mark the outer margins of mandibles reddish. Head inclined downwards. The larva placed on a horizontal surface always remains in a curved position. Larval and resting stages occupy 10 to 13 days.

Description of one or two days' old pupa is given below :—

Length 6 mm. General colour is yellowish ; apical joints of flagellum, all tibiæ, tarsi, and mouth-parts, whitish.

Head.—Labrum, mandibles, clypeus, eyes, antennæ and its joints distinct. Ligula and palpi exserted, and placed below the thorax parallel to the longitudinal axis of the pupa, between the tarsi of the legs which are folded symmetrically on the ventral surface. Eyes and ocelli can also be traced feebly.

Thorax.—From above smooth and shining, all sutures well marked; two longitudinal depressions on the meso-thorax; median segment posteriorly vertically truncate. Wings in rudimentary stage, lying obliquely on meso- and meta-pleura.

Abdomen.—Six or seven segments distinct, a little longer than broad, much narrowed towards the apex.

FIG. 15. CERATINA VIRIDISSIMA PUPA IN CELL, AND EMPTY CELL (I. I. L.)

The pupa, when placed on a horizontal surface, moves the abdomen right and left. By this motion it cannot go forward or backward, but can move more or less in a curve. Another noteworthy point in this connection is that the full-grown larva does not spin any cocoon, consequently the pupa is always found naked in a cell (Fig. 15). Changes in the colouration of the pupa take place in the same way as in other Aculeates. First, the eyes become pink and ocelli chestnut brown; gradually they turn black. The thorax and abdomen by degrees become green, and then the thin pellicle covering the pupa is shed and the perfect bee appears in its charming colour. Pupal stage lasts from 11 to 18 days.

Thus from egg to imago the bee takes from four to five weeks.

Egg stage ...	...	3	to	4	days.
Larval stage including 'Resting stage'	...	10	,,	13	,,
Pupal stage ...	...	11	,,	18	,,
TOTAL	...	24	,,	35	days.

As already noticed, the female bee nests in reed, thatch, hollowed-out dry branches of trees and dry shoots of bamboo. The first cell

is started right inside the hollow and the last cell is finished near the entrance (open end) : consequently if in the cell constructed last there is an egg, the cell constructed 1st (*i.e.*, the last cell counted from the open end) would contain a full-grown or a nearly full-grown larva. Naturally enough the inmate of the first cell becomes an imago, while the occupants of other cells are still in pupal and larval stage. How does the bee of this cell manage to come out of the nest when the exit is blocked ? After repeated observations I have come to the conclusion that the bees remain in their respective cells after shedding pupal skins and wait patiently there till the inmates of the succeeding cells leave a clear passage for them to emerge from the nest.

The bee pupa lies in a cell with head towards the closed end of the nest. On reaching the imago stage it stands on its legs and instinctively tries to walk forward and backwards. It pushes the sawdust plugs, and if the adjoining cells are occupied, the plugs will remain intact ; but if, on the other hand, the next cell (towards the open end) is vacant, the bee in her backward motion will demolish the sawdust wall and escape from the nest.

At night these bees hide themselves in such hollows as they choose for their nests, the mother bee always confining herself to her own nest. Early in the morning, five or six of these bees may be found huddled together in the central hollow of a single dried shoot of a bamboo.

Enemies.—Tiny black '*Chalcid*' parasites have been bred from the cells of this bee. In one cell there may be found as many as four dirty white larvæ feeding on the bee-larva. These larvæ, when full fed, do not spin any cocoon, but simply cast off their skins and pupate. The pupa is naked, white, about 3 mm. to 4 mm. in length, with all the limbs of the imago. About two days after pupation the eyes turn pinkish and gradually become deeper in colour. On the following day the whole of the body turns black and a couple of days after the parasite emerges.

Economic.—We have seen that *C. viridissima* stores pollen and honey in her cells. In order to facilitate the work of gathering

pollen, nature has furnished her with peculiarly modified hairs. On her tibiæ the hairs are branched and forked (as shown in figure 16; Fig. 16*a* shows a single hair magnified). Thus when she buries herself and rolls in the blossom, pollen grains adhere to these hairs. As she flies from one flower to another of the same plant, pollen grains of the one come in contact and stick to the stigma of the other and pollenize it. Similarly when she flies from one plant to another cross-pollination is accomplished. It will be clear from this that from an economic point of view this bee is very valuable in fruit and flower gardens.

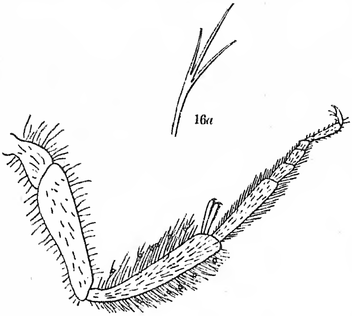


FIG. 16.—BRANCHED HAIRS ON THE TIBIA OF CERATINA VIRIDISSIMA.

FIG. 16*a*.—A SINGLE HAIR MAGNIFIED.

FAMILY FORMICIDÆ.

Dorylus labiatus, Shuck.

In the month of February each year males of this species, which are very wasp-like in appearance (Fig. 17), generally come at night into houses attracted by light. Workers have been found twice a year in large numbers; once in February and again in August. In size they are very much smaller than the males, in habits they are usually carnivorous. One afternoon (20th August, 1908) after a brisk

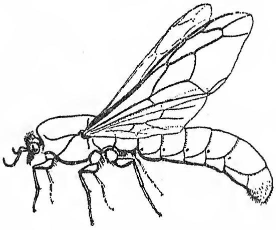


FIG. 17.—DORYLUS LABIATUS MALE—1⅓ (I. I. L)

shower of rain workers of this species came out in large numbers from their nest which was underground, near the foot of a wall. On this wall at that time were also moving upwards workers of *Phidole indica* with males, eggs, larvæ and pupæ. The *labiatus* workers attacked them and, grasping them between the mandibles, ran into the nest. On digging up the nest a little, I found several *Phidole indica,* Mayr., workers cut into pieces or badly mutilated.

Workers of this species are blind, but it was interesting to behold them pouncing on the *Phidole* workers with great precision. They live underground chiefly on animal food, and hunt small ants and little living things which multiply so enormously as to become a nuisance at times. *D. labiatus* in this respect is a beneficial ant to some extent.

Dorylus orientalis, Westw., is a species very closely allied to the above. Males of this species can be distinguished from those of *labiatus* by their smaller size and broader mandibles, and workers by the number of antennal joints which are nine in the case of the former and ten in that of the latter.

Workers of this species (Fig. 18) are injurious insects, because they have been observed to actually eat up healthy plant tissue. At Pusa they have been found to damage vegetable crops, but never seriously.

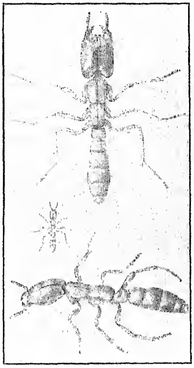


FIG. 18.—DORYLUS ORIENTALIS WORKERS. (I. I. L.)

Platythyrea victoriæ, Forel.

This ant is found walking on the trunk of trees examining depressions and spaces covered by loosened bark. I have seen this ant attacking a small tree spider which was hidden under a portion of the bark on an old *Ficus* tree. As soon as the ant approached the spider, the latter jumped out and hid itself in another place. The ant followed it there and the spider returned to its first hiding place. Thus five times was the spider ousted from its retreat and attacked but it always managed to escape unhurt by its agile movements.

Diacamma vagans, Smith.

This ant is seen at Pusa throughout the year and is one of the commonest insects found here. Nests are underground, at the base of big old trees, and near the roots of bamboo clumps. Pupæ of this species are encased in dark-brown cocoons. Outside the nests are noticed generally severed heads of *Camponotus compressus*, F.

Sima rufonigra, Jerd.

Nests of this species are generally found high up in the main trunk or branches of trees, and sometimes in bamboos also. I found one nest in a dried deformed bamboo standing in the midst of a thick clump. Neat and somewhat circular holes were visible on the outside (Fig. 19). These were the entrances to the nest. Fig. 20 represents the cross-section of the bamboo piece; 'a' is the central hollow, b & c mark the position of passages inside the nest.

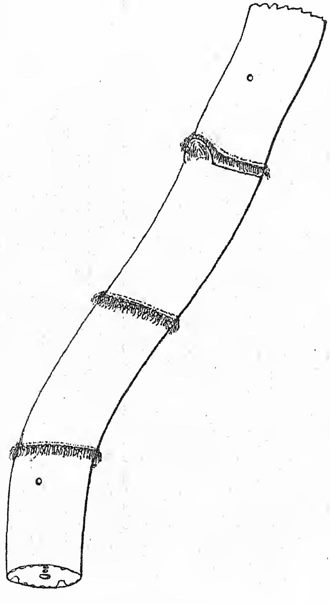


FIG. 19.—NEST OF SIMA RUFONIGRA IN A DRIED DEFORMED BAMBOO.

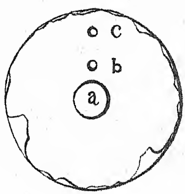
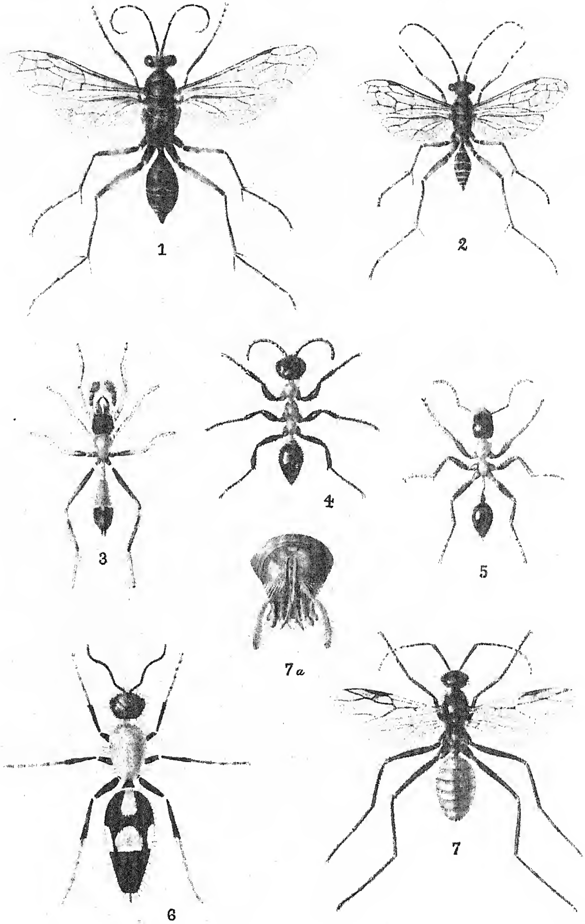


FIG. 20.—CROSS SECTION OF THE ABOVE SHOWING THE POSITION OF PASSAGES LEADING INSIDE THE NEST.


1
2
3
4
5
7a
6
7

EXPLANATION OF PLATE XIV.

1. Pseudagenia blanda ♀ } Magnified about 3 times.
2. " " ♂ }
3. Spider which mimicks Sima rufonigra ☿ × 3.
4. Methoca rufonigra ♀ × 3.
5. Sima rufonigra ☿ × 3.
6. Mutilla sp. ♀ × 8.
7. Myrmecocystus setipes ♂ × 3.

7a. Last segment of the above showing exserted genetalia. } × 8.

Larvæ are white, cylindrical, with ends rounded, 5 mm. in length. There is a fine medial longitudinal black line above extending over a few segments of the body in the middle. The integument is transparent and through it is visible a black ring encircling the central portion of the body. The head is bent downwards and rests on the ventral side, forming an emargination in the convexity of the undersurface. Once I observed workers of this species attacking those of the 'Harvesting Ant'—*Holcomyrmex scabriceps*, Mayr., which were returning to their nest laden with grains of oats from a neighbouring field. *Rufonigra* did not carry '*scabriceps*' living or dead to the nest, nor did they plunder the latter, but simply took pleasure in killing them or leaving them half dead on the field. The workers of this species are mimicked by a spider which is shown on Pl. III, fig. 3; fig. 5 is the worker.

Sima allaborans, Walk.

Nests of this species have been found in the tender shoots bamboos, and also in the main trunk and branches of trees. In the former case the central hollow is utilised for the nest.

These ants when disturbed discharge a drop of white fluid through the anal tube.

Cataulacus taprobanæ, Sm. and *C. latus* Forel.

Cataulacus taprobanæ, Smith, has been found nesting in the hollow of bamboo shoots and *Cataulacus latus*, Forel, in the branches of 'teak' and 'sarish' trees. Ants of both the species are jet black and very inactive; the former is smaller in size than the latter and has orange-red tibiæ.

Cremastogaster subnuda, Mayr.

This species is strictly a tree-ant. The nest may be either in the main trunk or in one of the branches of the tree on which these ants are found running. On a Ber tree a nest was found in the hollow made by the 'Ber shoot borer' (*Arbela tetraonis*, Mo). On the branches of a young Ber tree I noticed a couple of Mantis egg-cases which were infested with these ants; some were going inside

them and others were walking on the outside. On opening the egg-cases it was found that the portions visited by the ants were simply dry and empty, but the innermost portion was quite intact.

These ants were observed attending Mealy bugs, *Cerococcus sp.*, on tender Ber shoots, and also the Lac insect (*Tachardia lacca*). These ants in their eagerness to obtain honey-dew from the latter often nip off the ends of the white filaments, the two anterior of which are connected with the respiratory apparatus of the Lac insect, and thus kill it.

Pupæ of this species are naked and the sexes winged.

Monomorium indicum, Forel.

During wet weather individuals of this species enormously increase in number and often become a nuisance in houses. Their nests exist generally underground and sometimes not a single hole in the pucca masonry is left unoccupied. In the monsoon season of 1909 a very large colony of this species established itself in the College building at Pusa, and there were no less than a score of well populated nests scattered all over the building. Individuals of these nests became extremely abundant and nothing was safe from their attack. They got into cages in which insects were reared; they spoiled fresh specimens of insects on setting boards, and old specimens in the boxes when they were left opened on the working table for a while; in short, they grew very troublesome and I undertook to drive them out of the building. I began with pouring simple kerosene oil into all the nests. This measure succeeded in killing a few workers and making the rest quit the nests, only to occupy the first available hole in the vicinity. Kerosene-treatment was extended to these newly occupied holes which were quitted likewise. Thus after the fourth treatment no nest was left in the floor, but the ants were not entirely got rid of. They took to occupying holes in the walls. Kerosene oil in these cases could not penetrate so easily and so far inside the nests as when these were situated in the floor. Consequently the ants did not vacate the nests this time, but emerged through another hole below or above the one

through which kerosene oil was injected and after a couple of days began to use the original entrance to the nest again.

Next I plugged up all holes with white putty after pouring in kerosene oil. This stopped the emergence of the ants, but only temporarily. After a few days I found the plugs bored through and streams of workers flowing out. I then tried white putty well rubbed with kerosene oil to stop the holes, but with little success. My next effort was to stop the holes after injecting kerosene, with white putty thoroughly rubbed into a paste with pure Benzene. This measure succeeded very well, and although it is now more than two years ago that the plugs were put on they are still intact. I am not inclined to believe that the ants were stifled and thus died inside, but in all probability they escaped, how and from where I am unable to tell. I only know this much, that they were never seen afterwards in the College building.

From all that I have seen I am of opinion that the success of a particular measure, undertaken to drive this species out of a building, depends more on the persistence and perseverance with which a measure is carried out than on the property of the substance used. What I have found necessary in the case of this ant is to make the whole colony feel that there is a superior force which is bent upon extirpating them; and this can easily be done by daily killing a large number of these ants continuously for some days.

By daily pouring kerosene in nests which were in the floor of the College building I killed several workers, but could never finish them wholesale. The ants felt much disconcerted there, and resorted to the holes in the walls which they thought to be more secure, but when they were persecuted still more vigorously in their new abode, they realized they were not safe and were consequently under the painful necessity of abandoning the building.

One morning (3rd July 1909) I observed the inmates of a nest marching out with young ones. Close to the nest was sitting a Muscid fly (*Ochromyia* sp.) which attacked from time to time the larvæ and pupæ that were being carried by the workers. The fly never snatched the victim from the grasp of the ant, but simply

'licked' it from its place with the proboscis, which when withdrawn left the larva or pupa quite shrivelled up.

Monomorium destructor, Jerd.

These are very pretty-looking small red ants, with a dark-brown abdomen, which has a sordid yellow colour at the base. They are found in houses usually on substances which have a little grease sticking on them, *e.g.*, combs, hair brushes, corks of phials containing hair oils, etc. On one occasion, however, I noticed a long stream of workers of this species emerging from my store room, each worker carrying a particle of some white substance between the mandibles. I traced them back to a vessel containing wheat flour in which hundreds of these ants were gathered. On another occasion, I traced them to a hole in a Sann-hemp stick in the wall of a thatched hut. The central portion of a Sann-hemp stick is pithy; this soft substance was removed by these ants and a long cavity formed in the stick extending from base to top to serve as a nest. From this nest I obtained winged males (20th July 1908).

The ants of this species bite severely and their bite is very painful. This fact is known, perhaps, to other ants also for they seldom come near its nest. But should they ever happen to pass close by it, they have to suffer the painful consequence of their negligence. A *Diacamma vagans* ☿ was once thus chastised. It was walking in its usual leisurely fashion when some twenty or thirty of these red ants fell on it on my opening the Sann-hemp stick containing the nest. The *Diacamma* was very much disconcerted for all the *M. destructor* clung to it, curling their little bodies round its legs, and pinching with their mandibles. The big ant ran for its life, occasionally giving a jerk to the legs or passing them through the mandibles.

I have observed these ants attending *Coccids* (*Dactylopius* sp.) on a wild bush.

Monomorium latinode, Mayr.

A portion of the trunk of a tree was scooped out, and the wood inside the hollow appeared to be decayed. On removing a few chips

of wood I found regular chambers and galleries made therein, thickly inhabited by workers, pupæ, larvæ and eggs of *Monomorium latinode.*

Iridomyrmex anceps, Roger.

This species nests in sandy soil near the roots of plants infested with Aphides. In case the nest is situated in an open place, Aphis-infested plants are sure to be found in the vicinity. Well beaten tracks diverge from the nest into different directions and these tracks appear prominently in sandy soil after a shower of rain.

These ants have been observed attending Aphides on a plant locally known as Mukna (*Leppia nodiflora*). On each flower and between the leaves about a dozen of these were present. A species of Membracid on Sissu is also attended by this species, and I have seen these ants visiting the sugary glands of *Cassia orientalis* also. Dead insects even receive their attention. I saw some 40 or 50 workers of this on a dead ' Mole cricket ' (*Gryllotalpa africana*, Pal. B) and one worker was noticed once carrying a dead Sphegid wasp (*Crabro sp*).

In the same area there may be several nests separated from each other by a distance of a few yards only, but all belonging to a big central one. Workers of one nest can freely go into any other nest.

The nests are deep, but eggs and larvæ are always deposited in that layer of earth which is neither dry nor moist. In February these are found at the depth of barely one inch in large masses and in July at 10 to 12 inches depth, but only a few in number. Pupæ are naked, *i.e.*, not enclosed in cocoons. Winged males were obtained from the nests in August (20th August 1908). Living specimens of this species when squeezed between the fingers emit a peculiar kind of odour.

Tapinoma melanocephalum, Fabr.

Workers of this species have been observed attending (1) ' Wax scale insects ' (*Ceroplastes* sp.) on Custard Apple (*Anona squamosa*), (2) Coccids on tender Bamboo shoots, (3) Aphides and (4) Caterpillars of *Catochrysops cnejus* F. (*Lycænidæ*).

The nests are situated underground, deep and very populous. Females have been secured in the month of July from the nests.

Œcophylla smaragdina, F.

This is the commonest ant at Pusa, and workers of this species are seen throughout the year. In cold weather they are not so active as during summer and the rains.

Their colonies exist on Lime, Mango, Litchi, Pipal, Jaman, Teak, Sissoo and many other trees. Nests are constructed of leaves folded and held together by white silky web, and are always distinguished by their large size from other small leafy constructions which are usually scattered all over a tree and are the "Cattle sheds" or "byres" of this ant.

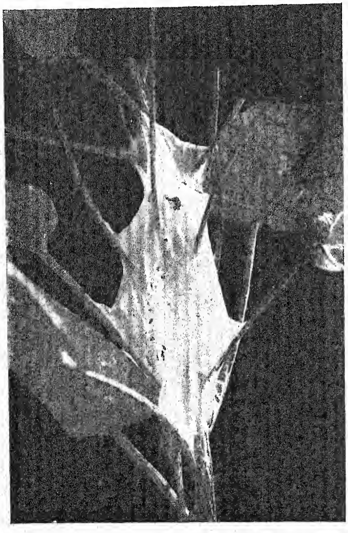


FIG. 21.—WEBBING of ŒCOPHYLLA SMARAGDINA ON PIPAL SHOOT ENCLOSING LECANIUM HESPERIDUM. (I. I. L.)

These byres contain generally Coccids—*Lecanium hesperidum* (on Sissoo and Pipal) (Fig. 21). Workers have also been observed attending *Lecanium nigrum*, *Icerya* sp., *Hilda bengalensis* and *Oxyrhachis tarandus*. Besides, they carry all sorts of miscellaneous insects to their nests, *e.g.*, caterpillars living or dead, dead grasshoppers, many flies, beetles, moths and sometimes their wings alone, bugs, small dead ants, etc. They congregate in large num-

bers on the trunk or near the foot of such trees as have their colonies on them. Should any living insect pass close by them, they would at once rush on it, and after killing would remove it to their nest. Their mode of attacking and killing their victims is very interesting. The following observation, which I quote from my note-book, will fully describe it :—

Pusa, January 30, 1908.—" A very curious thing I have noticed. There is a big pipal tree on the other side of the river Gandaki. On the trunk of this tree not very high from the ground I observed three workers of *smaragdina* dragging a helpless *myrmecocystus setipes*, ☿ maj., up the tree to their nest. I picked up the *setipes* and *smaragdina* workers also clung fast to it. On disengaging the *setipes* from the firm grip of *smaragdina* worker I noticed that the *setipes* was not yet quite dead. I knew that *smaragdina* was a great cattle tender ; I had seen, on several previous occasions, the workers carrying to their nests dead insects pertaining to nearly all the different orders of insects. I have mentioned elsewhere their extreme fondness for living caterpillars, but I had never seen before workers of *smaragdina* carrying *setipes* to their nest living or dead. Had the specimen of *setipes* been dead, it would not have excited so much curiosity.

" I brought a stray worker of *setipes* to the foot of this tree where *smaragdina* workers were sitting in a large group. To ascertain whether there exist any hostile feelings between the two species I picked up the *setipes* by means of my forceps, and presented it to a group of three or four workers of *smaragdina*. These at once rushed on the *setipes* and one of the *smaragdina* firmly caught hold of one of the legs of the *setipes*. I at once removed the *setipes* with *smaragdina* clinging to its legs. I pinched severely the latter, but it did not let go its hold. I chopped off the abdomen, but the grasp was still fast. I cut off the thorax, but the ' Bulldog grip ' was not loosened.

" Just as I turned my eyes to the other side of the trunk I beheld another interesting sight. Near the foot of the tree on the ground was stretched a *setipes* worker, its legs being in the tight

grasp of *smaragdina* workers. Each leg of the former was pulled out by a worker of the latter and was stretched as straight as possible, the *smaragdina* worker stretching itself in its turn, fixing the claws in the ground. Thus six workers of *smaragdina* were engaged with one worker of *setipes* which appeared more or less like a specimen on a setting board. At intervals it made a restless convulsive movement, but the grasp was all the more tightened. It began furiously to open and close the mandibles, but one more *smaragdina* worker very dexterously jumped and caught hold of the out-stretched jaw. The other jaw was similarly grasped by another worker. Thus the *setipes* was rendered motionless, and its escape hopeless. It was kept stretched in this 'set position' till it grew stiff (Fig. 22). A *smaragdina* worker occasionally loosened its hold to see if the victim contracted its leg, and if it did so, it was stretched with a vengeance. I watched this for half an hour when the *smaragdina* workers let go their grip one by one, leaving only three workers behind to remove it to the nest.

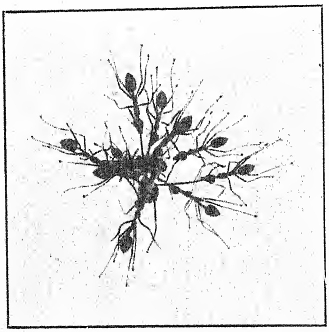


FIG. 22.—MYRMECOCYSTUS SETIPES WORKER BEING STRETCHED TO DEATH BY THE WORKERS OF ŒCOPHYLLA SMARAGDINA. (FROM A PHOTOGRAPH.)

"To definitely learn the mode of *smaragdina*'s attack on *setipes* I brought another stray specimen of the latter; it was a worker minor. I left it close to the foot of the tree. It showed some signs of terror and was just running away when a *smaragdina* worker caught hold of one of its legs. The *setipes* doubled itself, attacked *smaragdina* in return with mandibles wide open, but was soon overpowered by an overwhelming majority of the enemy. As described above they 'set' it and in 15 minutes' time it was more than half dead

and was consequently removed up the tree. In this case only four workers joined in the attack, and in a comparatively short time the *setipes* was done with. The fact of the victim being a worker minor, accounts for less time and less number of *smaragdina* workers required to subdue it.

"To determine which is stronger of the two in a single-handed fight I put one *smaragdina* worker against one *setipes* worker. The former played its usual trick of grasping the leg and the *setipes* doubled itself to bite off *smaragdina*'s thorax. The *smaragdina* at once put its abdomen between the thorax and the strong mandibles of the *setipes* to obviously save the body from being cut into two pieces. The thorax of *smaragdina* is generally very narrow and delicate, and especially so at the apex of the metathorax where it is joined on to the abdomen, by means of a thin pedicel, the spot aimed at by the *setipes*. The abdomen was squeezed and drops of a colourless fluid oozed out. This fluid appeared to be offensive to *setipes* for it never turned its mandibles again that way.

"The *smaragdina* being light in weight was dragged by the *setipes* for a few feet, but it still firmly clung to one of the legs. The *setipes* tried hard to shake off the clinging *smaragdina*, but in vain. After fifteen minutes' close scuffle both fell exhausted in each other's embrace."

On several subsequent occasions I observed workers of *Œcophylla smaragdina* killing beetles (*Opatrum sp.*)* and bugs in the aforesaid "stretching" manner. On another occasion I noticed on the trunk of a Sissoo tree scores of workers of this species constantly walking up and down. In a neighbouring plot I found a plant badly attacked by caterpillars. I took a leaf of this plant which was covered all over with dirty coloured caterpillars, and laid it close to the trunk of the Sissoo tree. The *smaragdina* workers noticing the caterpillars fell on them voraciously. They mutilated

* I have even seen the giant Carabid beetle (*Anthia sexguttata*) attacked and overpowered by members of these red tree ants. The process of killing by stretching of the legs always seems to be practised when living beetles are attacked. Death is probably due to stretching of the nerve-cords of the victim.—T. B. F.

them, cut them up on the spot and then carried them off, up the tree to their nests. One thing I marked with a special interest in this connection. There was no strife between the workers over the distribution of the booty. Whosoever managed to lay its mandibles first on a caterpillar was acknowledged the undisputed possessor.

On this tree I found several small *nests* (I took them to be such at first) which consisted of a few, say 15 or 16, sissoo leaves rolled up and fastened together by the white silky web. On taking down and opening up two or three of such nests I found they did not contain winged sexes of this ant, but were solely occupied by the workers and a few larvæ. On green leaves which formed the inner apartments were noticed Coccids (*Lecanium hesperidum*) in large numbers. I concluded, therefore, that these small leafy constructions were not the nests, as I took them at first to be, but were the cattle sheds of the big colony of this species of ant, which had established itself on the tree.

The workers take very great care of their cattle ; I have observed them on several occasions removing the Coccids very gently between their mandibles, from such leaves as get withered (on account of all the sap having been drained of) and laying them on to fresh leaves.

Like many other ants this species is also mimicked by spiders. In my collection I have two such spiders ; and resemblance in the case of one spider to the ant worker is exceedingly striking. The pupa of this species are found naked in the nest, *i.e.*, not encased in cocoons.

My friend Mr. P. C. Sen (Entomological Collector, Bengal) tells me that this ant is very common in certain parts of Eastern Bengal and Assam. Nests are generally found on mango trees, and consequently the workers of this species are very troublesome to mango pluckers in the mango season. On some trees they are so abundant that men cannot climb up for fear of their bite which is very painful. In such cases they pluck mangoes by means of bamboo-poles or some such other thing. This ant, though a serious nuisance in this way, serves a useful purpose on the other hand. In Eastern Bengal people tie a small basket to the end of a bamboo-pole which they raise and thurst into a big leafy nest of this ant.

A couple of sharp jerks are then given to the pole with the result that the larvæ, pupæ workers, etc., fall thick into the basket, which is taken down. To get rid of the workers and winged sexes handfuls of ashes are thrown into the basket. Larvæ and pupæ are picked out then and are used either alone or with powdered rice, as baits for catching fish.

It will not be out of place to quote here the following interesting note which appeared in the Journal of the Bombay Natural History Society, Vol. XIII, p. 536, under the signature of Mr. A. M. Long :—

"The Murries of Baster—the southernmost Native State in the Central Provinces—use the red ants as a regular article of diet.

"Throughout the year, but more especially during the dry season, the Purjas—a sub-class of the Murries—collect nests of red ants and after tearing them open shake out the contents into a cloth and beat the insects mature and immature into a pulpy mass with a stone, and when all are dead enclose them in a packet, about the size of a goose's egg made of *sal* leaves. In this condition the article is taken to the bazaar and sold for a pice. To prepare the squashed ants for food they are mixed with salt, turmeric and chillies and ground down between stones, and are then eaten raw with boiled rice. They are sometimes cooked up with rice flour, salt, chillies, etc., into a thick paste ; and in this condition the food is said to give the eater of it great power of resistance against fatigue and the sun's heat."

Economic—We have seen above that the workers of this species readily attack caterpillars, and consequently very few caterpillars are found, if at all, on such trees as have colonies of this ant established on them. Next we see that these ants tend Coccids and Membracids which are injurious insects inasmuch as they extract sap from the branches and shoots of trees on which they are found ; but pipal and sissoo trees, on which colonies of this ant generally exist, are so vigorous and healthy in growth that the damage done to them by these Coccids and Membracids never comes to any appreciable amount. Again, we notice that in one place the larvæ and the pupæ of this ant are used as baits for fishes in another

place as an article of regular diet. Last but not the least, in removing to its nests dead insects and their broken limbs, which if left on the ground would rot and decompose, this ant does the work of a good scavenger. Taking into consideration all the above points, I am of the opinion that this ant is both beneficial and useful, although in valuable fruit gardens it is sometimes very troublesome.

Myrmecocystus setipes, Forel.

Ants of this species are common at Pusa and are found throughout the year. They make their nests underground and I have seen these both in hard and in sandy soils, and also in high banks of earth. If the nest is a long-established one, the entrance to it is more or less a transverse slit, and not circular as in the case of many other ants. Outside the nest there is to be seen a heap of earth dug and thrown out. The transverse slit and the heap of earth outside a nest are characteristic features of the nest of *Myrmecocystus setipes*.

I have not been able to ascertain definitely the inner structure of a nest, but having dug up several of these, I conclude that the main path in a nest, after the entrance, lies in a horizontal direction for a little distance, then it gradually goes deeper and deeper in an oblique direction, after which it branches off into different sides, leading to various chambers set apart for definite purposes, *e.g.*, the eggs and larvæ chamber, the pupæ chamber, the Queen's chamber, lumber rooms, etc. In the last named room all sorts of rubbish is thrown, such as empty pupæ cases, wings, hard integument and useless parts of insects brought into the nest.

Workers of this species carry all sorts of things and insects to their nest, such as fruits of *Ficus* trees, millipedes, grasshoppers, Neuropterous insects, wasps, ants, beetles, moths, bugs, etc., living winged and wingless Termites are also carried into the nest in large numbers. In the case of winged ones the wings are clipped off and thrown into the 'lumber room' and the wingless ones are carried into the store chambers, where they are packed in groups of twenty to thirty. Plundering habits of this ant have also been observed.

Once a worker of *Iridomyrmex anceps* was carrying a dead Sphegid wasp (*Crabro sp.*) and a worker of *setipes* waylaid it. The last named caught hold of *anceps* and violently shook it with the dead wasp. The wasp dropped from the grasp of the *anceps* and the *anceps* from that of the *setipes*. The *setipes* could neither see the wasp nor the *anceps*, although both were lying close to it on the right hand side. The *setipes* commenced a search in the opposite direction and in the meantime another *anceps* turned up on the scene and both the *anceps* carried away the dead wasp. As regards the sight of these big ants, such as *Myrmecocystus setipes*, *Camponotus compressus*, *Sima rufonigra* and the like, my belief is that they can see in particular directions only. I have noticed workers of these grappling with their victims on different occasions and generally missing them after the first onslaught, though they were lying quite close by.

In the last week of March 1908 at Wazirabad and in the middle of April 1908 at Lahore (Punjab) I got beautiful winged specimens of a male ant. Most of these were collected on the banks of the Chenab and on wet soil, but on two different occasions I captured a couple of these near the entrance to a nest of *Myrmecocystus setipes* under circumstances which made me suspect these to belong to the nest, and to be the males of this species. This point was established when in March 1909 on my digging up a populous nest of this ant I found nearly a dozen insects, similar to the supposed males, running out of the nest. These males can fly to a very great height and (unlike other winged ants) cannot be caught easily by hand.

In the "Fauna of British India; Hymenoptera," Vol. II, p. 312, only the worker of this species is described; the females of this species were secured by me long ago and there was no difficulty experienced in identifying them, for the workers and the females are almost identical in general appearance, only the former are smaller and wingless and the latter larger and winged. The male bears no resemblance either to the female or to the worker in colour or appearance. I describe it as follows :—

Myrmecocystus setipes, Forel. ♂ (Plate XIV, Figs. 7 & 7a). Head not so broad as the thorax, covered from behind with long glistening silvery white hairs; mandibles narrow near the basal portion, wide in the middle, and having the apical portion formed into an acute triangular tooth, close to which there is another blunt tooth on the inner margin. On the outer surface there are a few large shallow punctures and long pale hairs; antennæ 13 jointed, scape very long, equal in length to about 8 basal joints of the flagellum; clypeus convex; eyes large and prominent; ocelli distinct, placed in a triangle on the vertex; a distinct fovea in front of the anterior ocellus, and from this runs a smooth longitudinal line down to the top of the frontal area. Thorax compressed; pronotum slightly below the level of the mesonotum which is convex and bears in the middle a smooth longitudinal line; scutellum prominent; metathorax gradually sloping towards the apex, covered with short, soft, white recumbent pubescence. Node of the pedicel is convex in front, concave from behind, covered with a few long white erect hairs. Abdomen cylindrical, segments glabrous above, their basal portion constricted, ventral side covered with long pale hairs. Genitalia very large, exserted. Head and thorax black, chalybeate in certain lights, remarkably so in fresh specimens. Legs (excepting coxæ, trochanter and the basal portion of femora which are black), apical joints of flagellum and the abdomen ferruginous. Wings hyaline, the nervures thick, radial cell fuscous.

Length 12 mm., expanse 17 mm.

Acantholepis frauenfeldi, Mayr., var. *bipartita*, Sm.

This is one of the fast running ants and is easily confounded with the other small black ant (*Prenolepis longicornis*, Latr.) which also runs very fast. I have seen the nests of this species underground near the foot of trees, bamboo clumps, and in cracks and hollows in pucca masonry. The workers are generally found running up and down the trunk of such trees as *Tectona, Delbergia, Ficus*, etc. Evidently they have their cattle byres on these trees for the ants that descend invariably have their abdomen considerably distended.

Once I noticed them congregating in large numbers on smoked combs of *Polistes hebræus* and *Apis florea*, F. These ants have been observed to attend Aphides on Ak (*Calotropis gigantica*) and Coccids (*Lecanium* sp.) on orange trees, and also to carry dead insects to the nest. Winged sexes have been obtained from the nests during July and August. Pupæ are encased in cocoons.

Prenolepis longicornis, Latr.

The nests of this species are generally underground and the entrance hole is sometimes covered with dead and fallen leaves. Once I came across a nest which was located in the trunk of a fig tree, just near its base. There was a big hollow in the trunk about a foot and a half from the ground. Inside this the wood was decayed and reduced to soft pulp. On my removing this soft woody material from one side I found underneath it countless workers, larvæ and eggs of this species and also tunnels and galleries leading far inside into the trunk.

From another nest which was discovered near a thatched house, and was hidden from view, being covered over with dead leaves, I secured a specimen of *Merismoderus bensoni*, Westw. (Paussidæ). This is one of the fast running species of ants.

Camponotus compressus, Fabr.

This species is very common at Pusa, workers being seen almost throughout the year. During the rains they become abundant, but get scarce towards winter.

The nests are generally found underground at the foot of trees and bamboo clumps. They are sometimes found in the walls of houses also.

On account of its sugar-hunting habits and excessive fondness for sweets this species becomes a regular nuisance, during wet weather, in store-rooms where jars of sugar and pots of jaggery are left without tight covers. The workers feed on dead insects also. The fleshy portion is extracted and consumed on the spot, but when a worker succeeds in chopping off a larger slice of flesh, it is seen

trotting off to the nest with it. Once I noticed them carrying the pupæ of *Apis florea*, F., which they extracted from the cells of a comb fallen on the ground.

This species is a well known 'cattle tender' and the workers have been observed feeding on the honey-dew exuded by :—

1. Membracids (*Oxyrhachis tarandus*, Fabr.) on Babul (*Acacia arabica.*).

2. Cercopids (*Machærota planitiæ*, Dist.) on Ber (*Zizyphus jujuba*).

3. Aphides : (*a*) on vegetable beans.
(*b*) A greenish-blue species on Maize (*Zea mays*).

4. Coccids : (*a*) *Asterolecanium miliaris*, Boisd. var. *robusta*, Gr., on Bamboo.
(*b*) *Dactylopius* sp. on a wild bush.
(*c*) The Lac Insect, *Tachardia lacca*, Kerr.

This ant is a source of regular annoyance to the lac grower. In their eagerness to obtain 'honey-dew' the workers of this species often nip off the white filaments, the two anterior of which are connected with the respiratory apparatus of the Lac Insect, the Coccid being killed consequently.

This species has been observed at Pusa to attend the caterpillars of *Catochrysops cnejus*, F. (*Lycænidæ*) also. Three or four workers may be seen with a single caterpillar at a time, some stroking it with the antennæ and others getting on its back. The caterpillar does not resent the overtures of the ant and in some cases it has been found essential to keep the ant and the caterpillar together for the successful rearing of the latter.

The caterpillar discharges through a crescent shaped aperture situated on the 7th segment a drop of a white, very slightly viscous fluid which is greedily licked off by the ant. The caterpillar can close or open this aperture at will, and, through the middle of this, the fluid is excreted. The ants are in the habit of examining, rather feeling, this portion with their mouthparts from time to time to ascertain if any fluid has collected there.

On days of brisk showers followed by close atmosphere during the rainy month of July the winged sexes of this species take flight just at the time when darkness sets in. On such evenings scores of females and males of this species are attracted to light.

A worker major was once observed moving about with the underside of the thorax touching the ground, the whole body stretched to its full length, turning the head from left to right and *vice versâ*, as fast as its massive ugly size admitted; in short, it was in an extremely annoyed and perplexed condition. I could not understand what had troubled it. After a closer examination I noticed a small reddish ant being very roughly caught, squeezed and lastly mutilated by the worker major. I picked up the small ant, but the corpse was too mangled to be identified. On subsequent occasions whenever I saw a worker major of this species in this dazed condition I was sure to find some dead or dying small ants close by. I have also witnessed *compressus*' wholesale massacre of the helpless Termites whenever the latter happened to be open to view.

In this species, I think the colony is founded by a fertilized female singlehanded. On three different occasions, while digging up some nests, I found an oval chamber inhabited by a single female of this species with about half a dozen young larvæ and two or three cocoons.

Polyrhachis simplex, Mayr.

I reproduce here my note on this species which has already appeared in 'Indian Insect Life.'

"Nests of this species are found on low bushes, high trees, under bamboo sheaths, and on sugarcane leaves. The nest is always constructed in such a way as cannot be easily discovered by a casual eye. A greater portion of it is covered over by leaves and the portion open to view is not easily recognisable. It looks from a distance as if it were made of clay and cowdung mixed with dry pieces of leaves, straw and grass. In reality it is a brown silky cobwebby material, over which are thickly and closely laid dry pieces of leaves,

straw, etc. Just as *Œcophylla smaragdina* workers make use of salivary threads secreted by their larvæ in folding the edges of leaves together, so do the workers of this species. They catch hold of the larvæ between the mandibles and carry them over to the places where the web is required to be spread. The larvæ go on laying and stretching threads mechanically as wanted. Other workers bring dry pieces of straw and spread them over the web while it is still fresh. When a nest is cut open from any part a few of the workers at once rush up to the spot and plant themselves as sentinels to guard the breach, while others remove to a secure place larvæ and pupæ or whatever be in that portion of the nest. After the chamber opened to view is cleared of what it contained, the workers hold the torn portions between their mandibles and pull inwards. Thus the aperture is made as narrow as possible, and then a couple of larvæ are brought and the web is drawn across the rent in the usual way. The whole inside of the nest is lined with the brown silky cobwebby material, and the partitions between different chambers are also made of this material, but without straw.

"Ants of this species also tend cattle for whose protection they prepare byres of the same cobwebby material and cover also in a similar manner as their nest. Such byres were found on a sugarcane leaf, and also on a weed, close to established nests of this species. Workers were seen going in and coming out of those cattle sheds. On removing the covering large clusters of sugarcane Aphis were found in the former and *Monophlebus* in the latter shed. Workers of this species have also been observed carrying a large dead fly to their nest. Pupæ are encased in light brown cocoons. The winged sexes were obtained from nests in August and September."

It has been said in the foregoing pages that the pupæ of *Œcophylla smaragdina* are naked, and those of *Myrmecocystus setipes* encased in cocoons. *Smaragdina* nests in trees, and *setipes* underground. The larvæ of the former produce silk threads and so do those of the latter. The former uses them in binding together the leaves of trees for the nest and the latter in spinning cocoons inside which

they pupate. The question, therefore, arises why should not the larvæ of *smaragdina* pupate inside cocoons when they can produce so much silk as enables them to prepare nests of such large dimensions; and why, on the other hand, should *setipes* not nest on trees when the larvæ can secrete silk thread which may be used for folding the leaves together? If it be urged that the *smaragdina* larvæ do not spin cocoons because they find the inside of the leafy nests quite soft and sheltered I shall quote the instance of *Polyrhachis simplex*, which to me appears to occupy an intermediate position in this respect, between the two species. The ant nests on trees, the larvæ are used like those of *smaragdina* for constructing the nest, all the apartments are lined with silk from inside, and yet the larvæ pupate inside cocoons. If, on the other hand, in the cattle tending habit of *smaragdina* and *simplex* is found an explanation for their nesting on trees, then the position of such ants as tend cattle, but nest underground, becomes unaccountable. In this connection *Iridomyrmex anceps* and *Camponotus compressus*, etc., may be taken as examples. If there is any particular reason or motive in this, perhaps the ants know it best; at least it is beyond my comprehension.

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MEMOIRS OF THE DEPARTMENT OF AGRICULTURE IN INDIA

INQUIRY INTO THE INSECTICIDAL ACTION OF SOME MINERAL AND OTHER COMPOUNDS ON CATERPILLARS

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INTRODUCTION.

The following paper gives the detailed results obtained in a large series of tests of poisons on caterpillars. These tests were made in the hope of finding a substitute for Arsenicals. When Lead Chromate was discovered the work was stopped as the practical result had been attained, but it is desirable to publish the detailed results as a contribution to the study of insecticides. Some of the various compounds found to have definite poisoning or deterrent action may be of value outside India though they are of no value here and the detailed results are on a large enough scale to be reliable. This work was done several years ago and its publication has been delayed by the pressure on both of us of other work.

The 21st October 1912.

H. M. L.
R. S. F.

INQUIRY INTO THE INSECTICIDAL ACTION OF SOME MINERAL AND OTHER COMPOUNDS ON CATERPILLARS.

BY

H. MAXWELL-LEFROY, M.A., F.E.S., F.Z.S.,

AND

R. S. FINLOW, B.SC., F.C.S.

The use of poisons for the destruction of insect-pests has become almost universal in modern agriculture where skilled labour is employed and where the value of the crops is sufficient to warrant a considerable expenditure in the prevention of loss from this cause. Though vegetable poisons were, perhaps, the earliest in use, as the *akh* plant or the *nim* in India, modern entomology has developed the use of virulent poisons, which can be applied in very small quantity and yet be sufficient to render growing plants poisonous to many classes of pests. Arsenic is the only poison now employed on a large scale to poison the food of insects, and its various compounds have been in constant use for over half a century. Compounds of arsenic all have one disadvantage, in that careless application renders the crops poisonous not only to insects but to cattle. The careful application of standard arsenical washes to a fodder crop, for instance, will give it immunity to many insect-pests such as leaf-eating caterpillars, grasshoppers, etc., but should the strength of the standard wash be exceeded, cattle to whom it is fed will show signs of arsenical poisoning. In the United States this does not appear to be a disadvantage, any crop that is sprayed being fenced from stray cattle that would be likely to feed in such a crop, but it has been recognised that the poisonous nature of the arsenic is

an almost insuperable objection to its general use in Indian Agriculture.

The use of arsenic as an insecticide appears to have been suggested originally by its poisonous action on human beings. The digestive processes of insects are of a different nature and it is reasonable to suppose that there may be compounds which are poisonous to plant-eating insects and innocuous to cattle and man. The use of borax as a cockroach poison is a case in point where an insect can be destroyed by a substance which is far less harmful to man and domestic animals.

The following pages give an account of the experiments made to determine how far other substances than arsenic were poisonous to plant-feeding insects. The basis of the enquiry was a slender one, as there was little to show what class of compound would be likely to be effective. Apart from theoretical considerations, a substance to be a practical success must be (1) readily obtainable, (2) unaffected by rain and atmospheric influences to a considerable extent, (3) cheap, (4) without effect on plants, (5) effective at weak strengths.

Substances soluble in water would be washed off by rain and would be liable to injuriously affect plant tissues; Copper sulphate is a substance distasteful to insects, but it is soluble in water and exerts a considerable poisonous influence on living plant tissues. Lime on the other hand is insoluble in water, resists atmospheric influences, but is ineffective unless applied very densely to plants. One of the advantages of arsenic is its virulent action. A plant sprayed with water containing as little as one part by weight of lead arseniate in one thousand is poisonous to many insects; at a strength of 1 in 500 (1 lb. in 50 gallons of water), the fluid is the standard spraying mixture and renders plants poisonous to all plant-eating insects. Paris green (Copper Aceto-Arsenite) is still more virulent and can be used in smaller quantities. Evidently then it would be an advantage to have a compound that is very insoluble in water, that is unaffected by the atmosphere, that will not injure the plant, and that will be effective when applied in small quantities. The choice of compounds to test was no easy matter; omitting arsenic

compounds, the compounds of boron are alone indicated among mineral compounds, unless we include such poisons as antimony, mercury, lead, which affect man. Borax and allied compounds were worth testing on the analogy of the cockroach poisoning, and were included on that account. Other known insect poisons, used mainly as contact poisons, did not seem worth testing as their action is known. These include (1) soaps, (2) petroleum and mineral oil, (3) alkaloids of tobacco and other plants, (4) such compounds as phenol in the form of carbolic acid, sanitary fluid, creosote oil, etc., (5) rosin, (6) sulphur. The last is a known specific for special pests such as red spider, but does not appear to act as a stomach poison to insects at the strength usually applied ; it was however included. With these considerations in view, a selection of insoluble compounds was made, which were tested with a number of compounds of boron. The substances selected were such as were readily obtainable or which were worth preparing for some special reason. The original aim was to investigate the comparative effect on insects of these compounds with a view to eliciting any general facts that might aid in the later selection of suitable compounds for final and exhaustive trial, working from these to a compound that would be a practical possibility on a large scale in the field.

Preliminary.—A set of tests were made on larvæ of *Caradrina exigua* feeding upon lucerne. Approximately equal quantities of the powdered substance were taken, by volume, and placed in wide-mouthed glass stoppered bottles with equal volumes of water (65. c.c.). The food was placed in the shaken up liquid, the bottle shaken up and the leaf removed and dried. All were given as much to eat as they required and were kept under the same conditions as normal larvæ which were reared upon unpoisoned food. The leaf was found not to be easily wetted so it was just dipped in alcohol and then into water to break the surface film ; the leaf was then easily wetted in the poisoned water. The following compounds were thus tested for one week, and as a result of the test those in italics were omitted from further tests as being unsuitable. Borax, Copper Sulphide, *Magnesium Carbonate*, Boracic Acid, Zinc Oxide, Antimony

Sulphide, *Iron Sulphide, Manganese Dioxide, Barium Carbonate, Magnesium Oxide,* Lead Carbonate, Lead Sulphide, Lead Peroxide (Red Lead), Barium Borate; Copper Borate, Lead Borate and Barium Oxalate, were afterwards added. The basis of selection of these substances excepting in the case of Borax and Boric Acid was the property of forming insoluble compounds with Phosphoric Acid which is said to be present in large quantities in the alimentary canal of caterpillars generally. It was thought that if this is the case, the alimentary process might be interfered with to such an extent as to incapacitate the caterpillars for further damage, by administering with its food, sufficient amounts of bodies which form insoluble compounds with phosphoric acid. As a result of these tests, an attempt was made to secure greater accuracy. It was found, for instance, that young larvæ were poisoned more rapidly than slightly older ones; also that larvæ nearly full grown were apt to pupate before their time, apparently under the influence of slight poisoning or because they objected to the food given. Larvæ more nearly of an age and not near to pupation were then used. It was decided that it was useless attempting to give known amounts of food and more accurate to give as much food as they could eat.

The chief way in which accuracy could be obtained was by using as far as possible chemically equivalent amounts of each compound. Some additional compounds were added as stated above, *viz.*, Barium Oxalate, Lead Borate and Copper Borate.

The amounts used are weighed in H. equivalents of Arsenic in Lead Arseniate ($Pb_3(AsO_4)_2$), taking 1 gramme of Lead Arseniate in 100 c.c. of water as standard.

The weights actually used are, per 300 c.c. of water :—

Lead Arseniate ..	(÷10)	89·87	formula assumed ($Pb_3(AsO_4)_2$)	3	gr. per 300 c.c.
Lead Carbonate ..	(÷ 2)	133·45	$PbCO_3$	4·44	,, ,, ,,
Lead Sulphide ..	(÷ 2)	119·5	PbS	3·96	,, ,, ,,
Red Lead ..	(÷ 6)	114·1	Pb_3O_4	3·7	,, ,, ,,
Barium Borate (?) ..	(÷12)	24	$Ba B_4 O_7$ (?)	0·8	,, ,, ,,
Boracic Acid ..	(÷ 3)	21	$B(OH)_3$	0·7	,, ,, ,,
Borax Aq. (10) ..	(÷12)	32	$Na_2 B_4 O_7 10H_2O$	1·0	,, ,, ,,
Copper Sulphide ..	(÷ 2)	47·83	CuS	1·6	,, ,, ,,

Zinc Oxide	.. (÷ 2) 40·7	ZnO.	1·3	gr. per 300 c.c.
Antimony Sulphide	.. (÷ 6) 56	Sb_2S_3	1·8	,, ,, ,,
Copper Borate (?)	.. (÷12) 18	CuB_4O_7 (?)	0·60	,, ,, ,,
Lead Borate (?)	.. (÷12) 30	PbB_4O_7 (?)	1·00	,, ,, ,,
Barium Oxalate	.. (÷ 2) 122	BaC_2O_4	4·1	,, ,, ,,

1 gr. per 100 c.c. is equivalent to 1 lb. of Lead Arseniate in 10 gallons of water, which is quite 5 times as strong as the standard wash and is three times as strong as the strongest wash ever used.

Estimation of poisoning effect.—The larvæ used were kept in boxes or open dishes, fed with fresh food dipped in the poisoned liquid. Every precaution was taken to ensure an uniform distribution of the poison in the liquid and of the liquid over the leaf. The leaf was then dried and sufficient given to the caterpillars. The amount actually given was so arranged that the larvæ would eat at least fifty per cent. of the food ; when too much was given the larvæ could pick out leaves not so much poisoned but by causing them to consume nearly all the leaf, the absorption of approximately equivalent quantities of poison was ensured. The larvæ were fed twice daily and were under observation at intervals throughout the day. As each died the time was noted on the cage slip. A sample cage slip runs as follows :—

Copper Borate. 1·5 gms. (per 300 c.c.) *C. Exigua.*

		No.	Time.	Multiple.	Average.
20 *caterpillars put in 6 p.m.*	.. .. 21. V.				
1 died 4 P. M.	.. .. 22. V.	1	22	22	
4 died in night of	.. .. 22. V.	4	30	120	
(3 parasitised removed).					
2 died in night of	.. .. 23. V.	2	54	108	
2 died 10 A.M.	.. .. 24. V.	2	66	132	
2 died 2 P.M.	.. .. 24. V.	2	70	140	
4 died 5 P.M.	.. .. 24. V.	4	71	284	
1 died in night	.. .. 24. V.	1	80	80	
(1 parasitised	.. .. 25. V.)				
		16		886	56
15 *put in 7 a.m.*	.. .. 25. V.				
2 died in night of	.. .. 26. V.	2	41	82	
2 died in noon	.. .. 27. V.	2	53	106	
1 died 5 P.M.	.. .. 27. V.	1	58	58	
4 died in night of	.. .. 27. V.	4	65	260	
4 died at 5 P.M.	.. .. 28. V.	4	82	328	
2 died in night	.. .. 28. V.	2	89	178	
		15		1012	67

		No.	Time.	Multiple.	Average.
10 *put in 8 a.m.*	1. *VI.*				
1 died at noon	1. VI.	1	4 ..	4	
7 died in night of	1. VI.	7	16	112	
1 died in night of	2. VI.	1	40	40	
(1 parasitised).					
3 died at noon	5. VI.	3	100	300	
		12		456	38

To compare these, the hours from time of being put in to time of death are put down on the right hand column. These figures are then averaged up and the average taken as the poisoning value of that compound at that strength and on that insect. The average in this case is 54 and the results shortly stated are that the poisoning period (Lethal Figure) of Copper Borate at ·5% on Caradrina exigua is 54 hours. The larger this figure the slower or less effective the poison. The figures for the compounds tested are tabulated below:—

TABLE I.

Name.	Amount %	Lethal Figure.	Number of caterpillars.
Copper Borate	·5	48	53
	·2	50	50
	1·23	40	73
Copper Sulphide	·53	48	55
Antimony Sulphide	·6	23	80
Red Lead	1·23	41	50
Lead Sulphide	1·3	40	58
Zinc Oxide	·43	45	42
Lead Carbonate	1·46	78	12
Barium Oxalate	1·36	none	..
Borax	·33	none	..
,, ...	1·03	41	18
Borax and Lac.	1·03 5·15	45	17
Boric Acid	·23	none	
,, ,, ...	·7	67	20
,, ,, and Lac.	·7 3·5	50	38
Barium Borate	·2	none	..
,, ,, ...	1·8	51	9
Lead Borate	·33	76	16

In the next table, the maximum, minimum and lethal figures are given for each compound for each kind of larva experimented with. The lethal figure is given as a fraction the numerator of which represents the average duration of life in hours and the denominator the number of larvæ killed in that time.

TABLE II.

Name.	Amount. %	Lethal figure. Minimum.	Mean.	Maximum.	Larva.
Copper Borate ..	·5	15/4	48/53	84/4	C. exigua.
	·5	7/1	36/12	54/3	P. littoralis
	·5	20/3	44/13	78/1	A. plexippus.
	·2	21/3	50/50	84/2	C. exigua.
	·2	15/2	42/7	66/2	A. plexippus.
	·2	18/2	62/10	90/2	P. littoralis.
	1·23	6/5	40/73	66/4	C. exigua.
	1·23	6/6	18/16	63/4	A. plexippus.
Copper Sulphide ..	·53	27/6	48/55	69/4	C. exigua.
	·53	16/1	38/5	52/1	P. littoralis.
	·53	18/2	49/6	78/1	A. plexippus.
Antimony Sulphide ..	·6	6/5	23/80	67/3	C. exigua.
	·6	7/5	19/23	54/2	A. plexippus.
Red Lead	1·23	7/4	41/50	66/6	C. exigua.
	1·23	24/3	36/13	57/1	A. plexippus.
	1·23	16/1	44/9	76/1	P. littoralis.
Lead Sulphide	1·3	9/9	40/58	125/2	C. exigua.
	1·3	16/2	40/10	60/2	A. plexippus.
Barium Oxalate ..	1·36	abandoned as without effect.			
Lead Carbonate ..	1·46	..	78/12	..	....
Zinc Oxide	·43	8/4	45/42	97/3	C. exigua.
" "	·43	no effect	(6 used)		A plexippus.
Borax	·33	no effect.	..	..	C. exigua.
	1·03	12/2	41/18	111/1	"
	1·03	19/2	36/9	79/1	P. littoralis.
	1·03	43/2	52/8	63/2	A. plexippus.
Borax and Lac ..	{1·03 / 5·16}	5/4	45/17	120/4	C. exigua.
(Soap)	5·16	30/1	42/11	72/1	A. plexippus. (starvation).
Boracic Acid	·23	no effect.			C. exigua.
	·7	15/1	67/20	92/3	C. exigua.
	·7	30/6	35/8	54/1	P. littoralis.
Boracic Acid and Lac ..	{·7 / 3·5}	24/2	50/38	75/4	C. exigua.
" "	"	died of starvation.			A. plexippus.
Barium Borate ..	0·2	no result.			
	1·8	36/1	54/9	62/4	C. exigua.
Lead Borate	·33	54/4	76/16	96/4	C. exigua.

These figures are on the whole apparently valuable; there is a general concordance between successive batches of the same species treated similarly; the average figure produced is a useful index and the high poisoning figure of antimony (23) really represents a very great mortality of the larvæ about that time. In the case of *Anosia plexippus*, a very marked disinclination to eat the leaf in some cases led to starvation and poisoning cannot be said to have occurred. As a result of these experiments, certain conclusions were arrived at; borates do not exert a marked poisoning effect; copper borate would appear to be poisonous as a copper salt not as a borate.

Of the Lead compounds, Lead Sulphide and Red Lead are equivalent, Lead Borate and Carbonate inferior. Barium compounds are apparently innocuous.

As a check, larvæ of *Sylepta* were fed in exactly the same way on untreated food and on food dipped in spirit and water.

The following are the results :—

No treatment.

20 caterpillars put in on 11th September.
17 ,, alive on 19th ,,
16 moths came out on between 25th September and 2nd October.
One pupa was killed in handling.

Fed with leaves dipped in spirit and water.

14 put in 12th September
11 alive 18th ,,
11 moths out between 25th September and 30th September. The preliminary treatment of the leaves with spirit, therefore, had no effect on the larvæ.

These results being indecisive, a larger range of compounds was chosen to elucidate if possible any general poisoning effects on caterpillars. The following Table (III) illustrates the results obtained with a varied assortment of substances all of which failed :—

TABLE III.

Substance.	Amount in 300 c.c. liquid.	Result.	Subject.
Acetamide	2·0	1 died in 30. 2 ,, ,, 48. 6 ,, ,, 60. 10 were left.	Caradrina.
Metaphenylene diamine hydrochloride ..	2·4	3 died in 30. 2 ,, ,, 54. 2 ,, ,, 60. 11 were left.	Caradrina.
Phenyl hydrazine hydro-chloride ..	1·8	2 died in 30. 6 ,, ,, 60. 12 were left.	Caradrina.
Potassium chloride	2·5	3 died in 24. 4 ,, ,, 30. 4 ,, ,, 54. 2 were parasitised. 7 were left.	Caradrina.

TABLE III—*contd.*

Substance.	Amount in 300 c.c. liquid.	Result.	Subject.
Sodium Carbonate	4·4	4 died in 30. 4 „ „ 54. 6 „ „ 60. 5 were left.	Caradrina.
Stannous Chloride	3·1	3 died in 30. 2 „ „ 54. 12 were left.	Caradrina.
Potassium Ferrocyanide	2·0	1 died in 24. 3 „ „ 36. 6 „ „ 60. 9 were left.	Caradrina.
Potassium Ferricyanide	1·8	2 died in 36. 5 „ „ 60. 12 were left.	Caradrina.
Magnesium Sulphate	4·1	1 died in 5. 4 „ „ 36. 1 was parasitised. 2 died in 54. 4 „ „ 60. 7 left.	Caradrina.
Picric Acid	2·5	1 died in 24. 3 „ „ 36. 5 „ „ 60. 10 were left.	Caradrina.
Potassium Bichromate	1·6	3 died in 36. 2 parasitised. 5 died in 60. 10 were left.	Caradrina.
Morphine	0·3	9 died in 84. 10 were left.	Caradrina.
Ammonium Persulphate	1·0	13 died in 13. 3 „ „ 24. 2 „ „ 36. 1 „ „ 52. 1 „ „ 100.	Caradrina. Average 23/20.
Ammonium Persulphate	1·0	1 died in 6. 2 „ „ 36. 7 „ „ 60. 9 were left.	Caradrina.
Ammonium Persulphate	1·0	1 died in 6. 6 „ „ 36. 5 „ „ 60. 1 „ „ 72. 2 „ „ 84.	Sylepta. Average 51/15.
Barium Peroxide	2·8	No effect.	Caradrina.
Sodium Benzoate	4·8	No effect. „ „	Caradrina. Pierid.
Caffein	0·3	1 died in 12. 3 „ „ 60. 10 „ „ 84. 5 were left.	Caradrina.
Sodium Tartrate	3·8	1 died in 60. 1 „ „ 168. 18 pupated.	Pierid.
Zinc Sulphide	1·5	No effect. „ „	Pierid. Caradrina.
Tartaric Acid	2·5	„ „	Caradrina.
Alum	5·0	„ „	„

TABLE III—*concld.*

Substance.	Amount in 300 c.c. liquid.	Result.	Subject.
		Died in 3 to 7 days.	Pierid.
Chrome Alum	5·5	No effect.	,,
		,, ,,	Caradrina.
Sulphur	0·5	,, ,,	,,
		,, ,,	Pierid.
Quinine	5·0	,, ,,	Caradrina.
		,, ,,	Pierid.
Carbolic Acid	3·0	,, ,,	Caradrina.
		One died on account of contact effect, the acid producing a sore on the skin.	Pierid.
Succinic Acid	1·9	No effect.	Caradrina.
		,, ,,	Pierid.
Sodium Succinate	2·8	No effect.	Caradrina.
		,, ,,	Pierid.
Tannic Acid	3·0	,, ,,	Caradrina.
		,, ,,	Pierid.
Gallic Acid	3·1	,, ,,	Caradrina.
		,, ,,	Pierid.
Brucine	0·3	,, ,,	Caradrina.
		,, ,,	Sylepta.

In Table IV we illustrate the action on three different caterpillars of varying strengths of one compound to show the degree of variation experienced—

TABLE IV.

Substance.	Amount in 300 c.c.	Number of caterpillars.	Figure.		Species.
	Gms.				
Copper Sulphide	·5	20	36·7		Prodenia.
,, ,, ...	·5	12	64		Caradrina.
,, ,, ...	·5	18	50	58	,,
,, ,, ...	·5	14	91		Pierid.
,, ,, ...	1·5	20	35		Prodenia.
,, ,, ...	1·5	13	76		Pierid.
,, ,, ...	1·5	12	58		Caradrina.
,, ,, ...	1·5	20	42	43	,,
,, ,, ...	1·5	19	35·8		,,
,, ,, ...	4·5	20	40		Prodenia.
,, ,, ...	4·5	18	26		Caradrina.
,, ,, ...	4·5	16	23	31	,,
,, ,, ...	4·5	20	41		,,
,, ,, ...	4·5	4	24		Anosia.
,, ,, ...	4·5	19	23		Pierid.
,, ,, ...	4·5	20	27·4		,,
,, ,, ...	9·0	20	32		Prodenia.
,, ,, ...	9·0	15	21		Caradrina.
,, ,, ...	9·0	18	33	20	,,
,, ,, ...	9·0	20	23·5		,,
,, ,, ...	9·0	18	19		Pierid.
,, ,, ...	9·0	20	17·5		,,

In Table V are shown the results of a number of compounds on various caterpillars; we give only the average figure for each experiment. As far as possible not less than 20 caterpillars, of even medium size, were used, but in some cases the experiments totalled up to over 100 individuals in all—

TABLE V.

Substance.	Amount in 300 c.c. water.	Lethal figures.								
		Sylepta.	Caradrina.	Anosia.	Marasmia.	Prodenia.	Diacrisia.	Cosmophila.	Pierid.	Ophiusa.
	Gms.									
Iodoform ..	4·4	10	15	..	..	..	..	13·6	..	..
	1·5	8·5	..	..	..	..	..	..	..	..
	0·5	10·5	51	..	..	..	18·0	..	..	10·7
	0·3	18·5	51	..	..	..	12·5	..	..	20·0
	1·0	..	..	..	..	..	..	..	12	..
Arsenious Oxide ..	2·0	11·8	..	..	..	..	..	..	..	..
Mercurous Iodide ..	7·5	15·6	14	..	..	..	..	..	..	..
Cuprous Cyanide ..	2·7	..	46	..	..	..	..	..	..	..
	1·9	11·2	41	..	33	..	17·3	25·5	..	..
	0·95	10·3	..	..	41·5	..	26·5	..	..	..
Lac	4·0	18·75	..	..	..	..	13·6	..	..	..
Borax .. .. Lac Soap ..	3·1 15·5	..	45	..	..	..	..	..	..	..
Boric Acid .. Lac	2·1 10·5	..	50	..	..	..	..	..	..	..
Boric Acid ..	2·1	..	67	..	..	35	..	..	..	..
Borax	3·1	..	41	42 52	..	36	..	..	..	..
	1·0	..	No effect	..	..	..	..	..	..	..
Copper Borate ..	3·7	..	40	40	..	..	..	..	..	..
	1·5	..	36 52	44	..	..	..	..	..	..
	0·6	..	50	42	..	62	..	..	..	..
Barium Borate ..	5·4	..	54	..	..	..	..	..	..	..
Lead Arseniate ..	3·0	17·7	16·5	..	..	26	44·8	..	8	..
	4·5	..	..	..	..	..	..	..	12	40·3
Lead Sulphide ..	3·9	..	40·0	40	..	..	..	..	..	..
Lead Carbonate ..	4·38	..	78·0	..	..	..	..	..	..	..
Red Lead ..	3·7	..	41·0	..	..	44	..	..	..	..
	4·7	..	..	36	..	..	..	..	..	..
Calcium Cyanamide	2·7	24	46	..	72·6	..	all lived.	..	..	..
Phenyl Hydrazine Hydrochloride ..	1·8	27·3	..	..	..	..	14·0	..	..	..
Mercuric Chloride ..	4·5	36·4	35	..	..	..	..	..	..	..
	1·0	36·3	..	..	..	..	18·5	..	..	..
	0·5	30·5	..	..	..	..	28·8	25·2	..	..
Antimony Sulphide	1·8	..	23	19	..	..	..	..	..	..
Copper Sulphide ..	4·5	..	30	24	..	40	..	..	27·7	..
	1·6	..	48	49	..	38	..	..	..	..
	1·5	..	45·2	..	..	35	..	..	76	..

TABLE V—*concld.*

Substance.	Amount in 300 c.c. water.	Lethal Figure.								
		Sylepta.	Caradrina.	Anosia.	Marasmia.	Prodenia.	Diacrisia.	Cosmophila.	Pierid.	Ophiusa.
	Gms.									
Copper Sulphide ..	0·5	..	57·0	..	..	36·7	..	..	91	..
Chloral Hydrate ..	2·75	..	35·8	..	..	..	..	..	..	..
Zinc Oxide ..	1·3	..	45·0	..	..	..	..	..	..	..
Strychnine ..	0·3	..	46	..	..	..	..	..	..	..
Brucine ..	0·3	..	67	..	..	..	..	..	26·5	..
Naphthaline ..	1·0	..	..	..	..	..	5	..	..	77·0
	2·0	..	..	..	..	..	..	..	..	36·1
Saccharin ..	2·0	58·7	..	..	..	..	..	..	..	..
Potassium Iodide ..	5·5	..	42	..	..	..	..	..	..	..

In Table VI are shown the same figures as in Table V, only put under each species of insect separately—

TABLE VI.

Substance.	Weight of substance in 300 c.c. water.	Caterpillars.	Average time required to kill, in hours.
	Gms.		
Iodoform	1·5	Sylepta	8·5
	4·4	,,	10·0
	0·5	,,	10·5
	0·3	,,	18·5
Arsenious Oxide	2·0	,,	11·8
Mercurous Iodide	7·5	,,	15·6
Cuprous Cyanide	1·9	,,	11·2
	0·95	,,	10·3
Lac	4·0	,,	18·75
Lead Arseniate	3·0	,,	17·7
Calcium Cyanamide	2·7	,,	24·0
Phenyl Hydrazine Hydrochloride.. ..	1·8	,,	27·3
Mercuric Chloride	0·5	,,	30·5
	4·5	,,	36·4
	1·0	,,	36·3
Saccharin	2·0	,,	58·7
Iodoform	4·4	Caradrina.	15
	0·5	,,	51
	0·3	,,	51
Mercurous Iodide	7·5	,,	14
Lead Arseniate	3·0	,,	16·5
Antimony Sulphide	1·8	,,	23·0
Copper Sulphide	4·5	,,	30·0
	1·5	,,	45·2
	1·6	,,	48·0
	0·5	,,	57
Chloral Hydrate	2·75	,,	35·8
Mercuric Chloride	4·5	,,	35·0

TABLE VI—*contd.*

Substance.	Weight of substance in 300 c.c. water.	Caterpillars.	Average time required to kill, in hours.
	Gms.		
Copper Borate	1·5	Caradrina	36·0
	3·7	,,	40·0
	1·5	,,	52·0
	0·6	,,	50·0
Lead Sulphide	3·9	,,	40·0
Red Lead	3·7	,,	41·0
Borax	3·1	,,	41
	1·0	,,	No effect.
Cuprous Cyanide	1·9	,,	41·2
	2·7	,,	46·0
Borax } Lac } Soap }	3·1 } 15·5 }	,,	45·0
Boric Acid } Lac }	2·1 } 10·5 }	,,	50·0
Zinc Oxide	1·3	,,	45·0
Cuprous Cyanide	2·7	,,	46
Strychnine	0·3	,,	46
Barium Borate	5·4	,,	54
Brucine	0·3	,,	67
Boric Acid	2·1	,,	67
Lead Carbonate	4·38	,,	78
Potassium Iodide	5·5	,,	42 for 8. 16 unaffected.
Copper Sulphide	4·5	Anosia.	24
	1·6	,,	49
Antimony Sulphide	1·8	,,	19
Copper Borate	3·7	,,	40
	0·6	,,	42
	1·5	,,	44
Red Lead	4·7	,,	36
Lead Sulphide	3·9	,,	40
Borax	3·1	,,	42
	3·1	,,	52
Cuprous Cyanide	1·9	Marasmia.	33
	0·95	,,	41·5
	2·7	,,	72·0
Borax	3·1	Prodenia.	36
Red Lead	3·7	,,	44
Copper Borate	0·6	,,	62
Boric Acid	2·1	,,	35
Copper Sulphide	0·5	,,	36·7
	4·5	,,	40·0
	1·5	,,	35·0
	1·6	,,	38·0
Lead Arseniate	3·0	,,	26·0
Copper Sulphide	0·5	Pierid.	91·0
	1·5	,,	76·0
	4·5	,,	27·7
Brucine	0·3	,,	26·5
Lead Arseniate	3·0	,,	8·0
	4·5	,,	12·0
Iodoform	1·0	,,	12·0
Cuprous Cyanide	1·9	Cosmophila.	25·5
Iodoform	4·4	,,	13·6
Mercuric Chloride	4·5	,,	25·2

TABLE VI—*concld.*

Substance.	Weight of substance in 300 c.c. water.	Caterpillars.	Average time required to kill, in hours.
	Gms.		
Phen. Hyd. Lac	1·8	Diacrisia.	140
	4·0	,,	136 (starved 3 days).
Mercuric Chloride	1·0	,,	18·5
	0·5	,,	28·8
Calcium Cyanamide	2·7	,,	all lived 8 days, no result.
	2·0	,,	
Cuprous Cyanide	0·95	,,	26·5
Lead Arseniate	1·9	,,	17·3
	1·0	,,	44·8
Iodoform	0·3	Diacrisia.	12·5
	0·5	,,	18·0
Naphthaline	1·0	,,	9·0
Lead Arseniate	4·5	Ophiusa.	40·3 leaves not eaten.
Calcium Cyanamide	2·7	,,	2 in 6 hours, 6 pupated in 5 to 13 days.
Iodoform	0·5	,,	10·7
	0·3	,,	20·0
Naphthaline	2·0	,,	36·1
	1·0	,,	77·0

The above experiments were all on caterpillars and material being available a small series were therefore done on a grasshopper (*Acridium aeruginosum*). The following are the results:—

Substance.	Amount.	No.	Time taken to kill.	Average.
	Gms.			
Copper Cyanide	·95	3	1 in 54 hours. 2 ,, 80 ,,	71
,, ,, ...	·95	3	1 ,, 36 ,, 1 ,, 72 ,, 1 ,, 96 ,,	63
Mercuric Chloride	1·0	3	2 ,, 60 ,, 1 ,, 84 ,,	68
Iodoform	1·0	5	3 ,, 44 ,, 1 ,, 92 ,, 1 ,, 126 ,,	70
,, ...	1·0	3	1 ,, 48 ,, 1 ,, 60 ,, 1 ,, 144 ,,	84
Lead Arseniate	3·0	4	2 ,, 7 ,, 2 ,, 72 ,,	37
,, ,, ...	3·0	4	2 ,, 14 ,, 1 ,, 26 ,, 1 ,, 120 ,,	48·5

Substance.	Amount.	No.	Time taken to kill.	Average.
	Gms.			
Calcium Cyanamide	2·7	4	3 in 30 hours. 1 ,, 21 days.	?
Iodoform	0·5	4	1 in 7 hours. 2 ,, 48 ,,	34·3
,, ...	0·5	3	2 ,, 60 ,, 1 ,, 108 ,,	76
,, ...	0·3	4	1 ,, 14 ,, 1 ,, 120 ,, 1 ,, 12 ,,	?
Naphthaline	2·0	4	2 ,, 80 ,, 1 ,, 12 ,, 1 ,, 16 ,,	?
,, ...	1·0	3	1 ,, 168 ,, 1 ,, 12 ,, 1 ,, 19 ,,	?

We class the compounds tested as follows—

Class I.—Average killing effect is under 20 hours :—

Iodoform.
Lead Arseniate.
Antimony Sulphide.
White Arsenic.
Mercuric Iodide.
Copper Cyanide.
Naphthaline.

Class II.—Average killing effect is from 20 to 40 hours :—

Copper Sulphide.
Strychnine.
Calcium Cyanamide.
Mercuric Chloride.
Copper Borate.
Red Lead.
Lead Sulphide.
Borax.
Boracic Acid.

Class III.—Average killing effect is from 40 to 100 hours :—

Lead Carbonate.
Barium Borate.

Zinc Oxide.
Lead Borate.
Lac and Borax.
Lac and Boric Acid.

The results of these experiments are not encouraging as they give us neither a definite principle nor any one compound to select. In class I are violent cattle or human poisons; Iodoform is useless for every reason; Antimony Sulphide is too poisonous; White Arsenic is impossible as it is soluble and poisonous; Mercuric Iodide is poisonous; Copper Cyanide is poisonous; Naphthaline is under certain circumstances extremely valuable and we deal with it further below.

Copper Sulphide might be valuable and its use is indicated. Strychnine is useless on every ground. In class II Calcium Cyanamide might have been promising had not its action on plants been too strong (see below). Mercuric Chloride is of course useless; Copper Borate might give good results; so might Red Lead or Lead Sulphide. Borax and Boracic Acid were abandoned after trial on plants (see below). Our attention is then directed to Naphthaline, Copper Sulphide, Copper Borate, Red Lead and Lead Sulphide.

On thinking over these experiments during the cold weather while waiting till fresh ones become possible, the Red Lead suggested the trial of commercial paints, *i.e.*, finely ground dry paints. A selection was obtained and tried. Table VII gives the results.

TABLE VII.

Diacrisia obliqua larvæ were used and all poisons at 1 lb. in 16 gallons of water (1·5 grammes per 300 c.c.)

Lemon Chrome—

3	died	in	72	hours.
7	,,	,,	96	,,
1	,,	,,	144	,,
1	,,	,,	192	,,

Eight pupated.

There was a distinct period of two days starvation before they fed at all, so that 48 hours should be deducted from these figures.

Ultramarine Blue—No action.
Yellow Ochre „ „

Prussian Blue—

1 died in 60 hours.
1 „ „ 72 „
2 „ „ 120 „
1 „ „ 192 „
15 pupated.

Burnt Umber —

6 died in 168 hours.
14 pupated.

Burnt Sienna—

1 died in 36 hours.
3 „ „ 44 „
16 pupated.

White Lead—

2 died in 192 hours.
18 pupated.

Oxide of Iron—

1 died in 96 hours.
4 „ „ 120 „
2 „ „ 144 „
13 pupated.

Of these Lemon Chrome seemed valuable and experiments on *Diacrisia obliqua* in the open gave very promising results. The caterpillars starved rather than eat plants sprayed with it at 1 lb. in 16 gallons. Accordingly this paint was analysed and found to contain 5 per cent. of Lead Chromate, with gypsum. Lead Chromate was then prepared pure and tested ; Barium Chromate was also

tested to see if it was the Chromate or the Lead, and if Barium could replace the Lead. The following results were obtained :—

Barium Chromate, 1·0 gramme in 300 c.c., *i.e.*, 1 lb. in 32 gallons of water.

15 caterpillars—1 died in 18 hours, 3 more in 66, the rest pupated after 100 or more hours. The difficulty of wetting cabbage leaf was a factor of importance.

On Caradrina exigua—

10 young put in :
1 missing in 2 days.
1 ,, ,, 4 ,,
1 ,, ,, 5 ,,
1 pupated ,, 5 ,,

the rest missing gradually, 1 survived, which pupated on the 13th day prematurely. The caterpillars eat each other vigorously from starvation as the poison upset them without killing them.

On Attacus ricini—

5 2nd instar worms put in 13th.
1 died on 15th.
3 ,, ,, 18th.
1 ,, ,, 29th.

Lead Chromate, 1·0 gramme in 300 c.c. or 1 lb. in 32 gallons of water :—

Pieris brassicæ—

15 caterpillars—3 died in 24 hours, 1 in 36, 1 in 96 (average 40), the rest pupated after the 4th day. The difficulty of wetting the leaves was a factor of importance.

Caradrina exigua—

10 larvæ, in 3 days only 7 left, on the 4th day 5 found dead, 1 died on the 5th day and the last on the 6th day. So long as they fed on each other, they did not touch the leaves at all. When they did, they died.

Attacus ricini—

Five 2nd stage worms: they refused to eat, only nibbling here and there; 2 died in 1 day, 3 in 2 days.

Diacrisia obliqua—

15 larvæ: they starved for 5 days—1 died on 5th day, 1 on 6th, 5 on 8th, 8 on the 10th.

15 larvæ: they starved for 5 days—1 died on 5th day, 1 on 6th, 11 on 8th, 2 on 9th.

The very marked feature of this, more marked even than with Barium Chromate is their refusal to eat it, as was also seen in the case of caterpillars in large cages where the plants were sprayed. We have seen no compound in which this aversion is quite so marked, and though we used very many Caradrina larvæ, which are fairly cannibalistic, it was only with these two compounds that the cannibalism was so extensive. It is clearly a very good deterrent and when starvation compels, a very good poison. Its general qualities are discussed below.

PART II.

It is clear that the figures obtained are not an absolute index of the poisonous effect of the various compounds particularly with some of the compounds in which the action was uncertain. In many cases, a few of the caterpillars were killed quite early while others lived for long periods; it appeared as if either the caterpillars accustomed themselves to some poisons, or they learnt to detect them, or they had a very varying degree of resistance to the poison or to starvation. In one case with borax the minimum was 12, the maximum 111. Where the maximum went over 96 hours, we rejected the compound even if the minimum was small, and of course the average figure does show the effect of the big maxima. To simplify the question and to give the results more simply, we give here the characteristic behaviour of each compound as derived from both observation of the behaviour of the caterpillars and the actual figures—

Class I.—Iodoform.
White Arsenic.
Mercuric Iodide.
Copper Cyanide.
Mercuric Chloride.
Naphthaline.
Lead Arseniate.
Antimony Sulphide.

Class II.—Calcium Cyanamide.
Lead Chromate.
Barium Chromate.
Lead Sulphide.
Lead Oxide (Red Lead).

Boracic Acid.
Borax.
Copper Sulphide.
Copper Borate.

Class III.—Lac, Borax and Soap.
Lac, Boric Acid.
Copper Tannate.
Lead Carbonate.
Barium Borate.
Zinc Oxide.
Lead Borate.

Class IV.—Barium Peroxide.
Sodium Benzoate.
Caffein.
Sodium Tartrate.
Zinc Sulphide.
Tartaric Acid.
Alum.
Chrome Alum.
Sulphur.
Quinine.
Carbolic Acid.
Succinic Acid.
Sodium Succinate.
Tannic Acid.
Gallic Acid.
Lac.
Chloral Hydrate.
Strychnine.
Brucine.
Saccharin.
Potassium Iodide.
Lemon Chrome Paint.
Ultramarine Blue Paint.

Yellow Ochre Paint.
Prussian Blue Paint.
Burnt Umber Paint.
Burnt Sienna Paint.
White Lead Paint.
Oxide of Iron Paint.
Lead Tannate.
Magnesium Carbonate.
Iron Sulphide.
Manganese Dioxide.
Barium Carbonate.
Magnesium Oxide.
Barium Oxalate.
Acetamide.
Metaphenylene Diamine Hydrochloride.
Phenyl Hydrazine Hydrochloride.
Potassium Chloride.
Sodium Carbonate.
Stannous Chloride.
Potassium Ferrocyanide.
,, Ferricyanide.
Magnesium Sulphate.
Picric Acid.
Potassium Bichromate.
Morphine.
Ammonium Persulphate.

The results are expressed as follows :—

The number of larvæ used (No. 10) ; " the minimum period " is the number killed in the shortest period (minimum 3/6 means " three killed in 6 hours ").

" The maximum period " is the number that died last and their period (maximum 2/30 means " two killed in 30 hours ") : average is the average figure as worked out on pages 281-2.

LEAD ARSENIATE. $Pb_3 (AsO_4)_2$.

Sylepta multilinealis—

3·0 grammes per 300 c.c.

No.	Minimum.	Maximum.	Average.	
10	3/6	2/30	17·9	17·7
20	7/7	4/37	16·9	
20	4/6	2/49	19·4	
20	6/6	1/49	16·6	

Caradrina exigua—

3·0 grammes per 300 c.c.

No.	Minimum.	Maximum.	Average.	
20	3/6	6/30	15	16·5
17	5/5	4/38	18	

Prodenia littoralis—

3·0 grammes per 300 c.c.

No.	Minimum.	Maximum.	Average.	
20	8/12	9/36	24	26
19	5/11	7/37	28	

Pierid—

3·0 grammes per 300 c.c.

No.	Minimum.	Maximum.	Average.	
20	14/6	2/12	7	8
20	10/4	10/14	9	
8	5/6	1/21	1/30	12

Diacrisia obliqua—

1·0 gramme per 300 c.c.

No.	Minimum.	Maximum.	Average.	
16	2/7	1/67	44·5	44·8
10	1/42	9/54	53	
20	5/7	1/78	37	

There was a marked refusal to feed at first.

Prodenia littoralis—

3·0 grammes per 300 c.c.

No. 7.—Minimum 5/30. Maximum 1/78. Average 40. Leaves not eaten at first.

Acridium aeruginosum—

3·0 grammes per 300 c.c.

No.	Minimum.	Maximum.	Average.
4	2/7	2/72	1/120
4	2/14	1/26	

In all cases, this insect was erratic; those that fed freely died quickly.

Ophiusa melicerte—

1·0 gramme per 300 c.c.

On growing plants in the open, *sprayed.*

Minimum 6/20. Maximum 1/252. Average 85.

3·0 grammes per 300 c.c. in cage.

Minimum 5/30. Maximum 1/68. Average 37.

The leaves were very little eaten at first.

Lead Arseniate may be, in a sense, taken as a standard, and the very strongest used in practice is 1·0 gramme per 300 c.c. usually much less. But to get comparative effects we must use our compounds stronger. We would point out that on the analogy of this particularly, any of the compounds that give a figure below 80 or 100, if they can be applied at that strength, are possible insecticides for field use.

White Arsenic. As_2O_3.

Sylepta multilinealis—

2·0 grammes per 300 c.c.

No.	Minimum.	Maximum.	Average.	
20	14/6	2/78	18	11·8
20	15/6	5/13	7·75	
20	10/7	3/26	12·25	
20	16/6	2/31	9·2	

Comparing this with Lead Arseniate, for the same insect, one sees how consistently this is more rapid in action. It is of course inadmissible as an insecticide owing to its burning action, but it is the really effective poisoning ingredient of all arsenicals.

ANTIMONY SULPHIDE. Sb_2S_3.

Caradrina exigua—

1·8 grammes per 300 c.c.

No. 80. Minimum 5/6. Maximum 3/67. Average 23.

Anosia plexippus—

1·8 grammes per 300 c.c.

No. 23. Minimum 5/7. Maximum 2/54. Average 19.

This is a very deadly compound; the experiment with *Caradrina* alone was done on lots varying from 4 to 20 and was so consistent that the figures are combined. It is inadmissible as a practical insecticide in India.

IODOFORM. CHI_3.

Sylepta derogata, Fabr.—

1·5 grammes per 300 c.c.

No.	Minimum.	Maximum.	Average.	
20	17/6	3/13	7	
20	17/7	3/11	8	
20	14/7	3/14	9	8·4
20	9/6	11/13	10	
20	16/7	4/13	8	

4·4 grammes per 300 c.c.

No.	Minimum.	Maximum.	Average.	
20	16/6	1/51	11·7	
20	14/6	6/13	8·1	10
18	11/6	7/13	9·3	

0·5 gramme per 300 c.c.

No.	Minimum.	Maximum.	Average.	
19	17/6	2/13	7	
20	19/6	1/13	6·3	
20	12/6	2/62	15	10·5
20	18/7	2/14	8	
20	5/6	2/42	19·8	
25	..	25/7	7	

0·3 gramme per 300 c.c.

No.	Minimum.	Maximum.	Average.	
20	14/6	2/61	16·5	
20	11/6	2/78	29·6	18·5
23	15/7	8/14	9·5	

In all these experiments, as in later ones, the caterpillars were kept in well-ventilated cages, as the fumes of Iodoform affected them very strongly.

Caradrina exigua—

0·3 gramme per 300 c.c.

No. 20. Minimum 4/7. Maximum 3/109. Average 51.

0·5 gramme per 300 c.c.

No. 12. Minimum 2/13. Maximum 3/85. Average 51.

4·4 grammes per 300 c.c.

No.	Minimum.	Maximum.	Average.	
20	6/6	2/27	12	10·5
20	19/8	1/32	9	

Pierid—

1·0 gramme per 300 c.c.

No. 8. Minimum 5/7. Maximum 3/19. Average 11·4.

Cosmophila sabulifera—

4·4 grammes per 300 c.c.

No. 10. Minimum 2/4. Maximum 2/25. Average 13·6.

Diacrisia Obliqua—

0·3 gramme per 300 c.c.

No.	Minimum.	Maximum.	Average.	
28	22/6	6/18	9	12·5
10	5/6	1/42	15·6	
10	5/7	5/19	13·	

0·5 gramme per 300 c.c.

No.	Minimum.	Maximum.	Average.	
30	15/30	15/42	36	18
10	5/7	5/31	19	
11	8/6	1/38	10	
10	..	10/7	7	

Ophiusa melicerte—

0·5 gramme per 300 c.c.

No. 8. Minimum 6/8. Maximum 1/20. Average 11.

0·3 gramme per 300 c.c.

No. 6. Maximum 6/20. Average 20.

Acridium aeruginosum—

1·0 gramme per 300 c.c.

No.	Minimum.	Maximum.	Average.
5	3/44	1/92	1/126
3	1/48	1/60	1/144

0·5 gramme per 300 c.c.

No.	Minimum.	Maximum.	Average.
4	1/7	2/48	1/34
3	2/60	1/108	1/76

0·3 gramme per 300 c.c.

No. 4. Minimum 1/14. Maximum 1/20. Average 1/298.

Except for the last, the experiments show the very great killing effect of this compound; the grasshopper used in the last would not eat leaves tainted with it and the resistant powers of a large grasshopper, are apparently greater than those of a caterpillar; the grasshopper simply refrained from food.

Iodoform is of course useless as an insecticide; but its action is very marked and is, we believe, worth following up with similar compounds. Iodoform is moderately volatile and its action in the open is of interest.

1·0 gramme per 300 c.c. on castor plants in the open, with *Ophiusa melicerte*—

No. 10—1/34. 1/96. 1/108. 2/124. 2/160. 1/184.

The plant was much burnt by the iodoform and the caterpillars simply tried spot after spot, trying to find a place free of iodoform.

MERCURIC CHLORIDE. $Hg\,Cl_2$.

Sylepta derogata—

0·5 gramme per 300 c.c.

No. 20. Minimum 3/6. Maximum 1/73. Average 30·5.

1·0 gramme per 300 c.c.

No.	Minimum.	Maximum.	Average.	
20	1/6	3/85	52·2	
20	7/8	1/62	26·8	36·3
24	12/14	2/62	30	

4·5 gramme per 300 c.c.

No.	Minimum.	Maximum.	Average.	
15	2/6	2/108	61	
19	2/6	1/73	34·5	36·4
20	8/8	1/38	13·6	

The irregularity in action is very marked but it is due to the fact that very early the caterpillars become affected by a small

amount of food and then lie moribund for hours. Although in this case the figures put this compound low, it is a very certain poison.

Caradrina exigua—

4·5 grammes per 300 c.c.

No. 20. Minimum 2/24. Maximum 18/36. Average 35.

Cosmophila sabulifera—

4·5 grammes per 300 c.c.

No. 10. Minimum 3/7. Maximum 2/49. Average 25·2.

Diacrisia obliqua—

0·5 gramme per 300 c.c.

No.	Minimum.	Maximum.	Average.	
10	5/18	1/42	25·2	28·8
10	6/18	2/78	32·4	

1·0 gramme per 300 c.c.

No.	Minimum.	Maximum.	Average.	
20	11/6	4/30	13·8	18·5
10	1/6	1/54	30·0	
10	7/7	1/31	11·8	

Acridium aeruginosum—

1·0 gramme per 300 c.c.

No. 3. Minimum 2/60. Maximum 1/84. Average 68.

Mercuric chloride is, as would be expected, a violent poison; it is soluble, totally unsuitable as an insecticide and merely illustrates the fact that an irritant poison affects insects as other organisms.

MERCURIC IODIDE. Hg_2I_2.

Sylepta derogata—

7·5 grammes per 300 c.c.

No.	Minimum.	Maximum.	Average.	
17	6/6	2/78	26	15·6
20	13/13	3/37	19	
20	6/7	2/37	15·3	
20	20/8	..	8	
20	12/7	8/14	10	

Caradrina exigua—

No.	Minimum.	Maximum.	Average.	
22	1/5 14/12	1/36	16·5	14
20	20/12	..	12	

Cosmophila sabulifera—

No. 10. Minimum 2/4. Maximum 3/36. Average 21·5.

This body is evidently a first-class poison, possibly combining the action of the mercury and the iodine as it is perceptibly quicker in action. It is to be classed with the arsenicals but is not useful in practice.

COPPER CYANIDE. $Cu(C.N.)_2$.

Sylepta derogata—

0·95 gramme per 300 c.c.

No. 20. Minimum 11/6. Maximum 1/37. Average 10·3.

1·9 grammes per 300 c.c.

No.	Minimum.	Maximum.	Average	
19	6/6	2/37	16·8	11·2
20	14/6	3/25	10	
20	8/7	2/28	12·5	
19	12/6	7/13	8·6	
20	20/8	..	8·0	
25	22/6	3/18	7·3	
20	16/6	2/30	9·6	
12	2/4	3/36	16·6	

Caradrina exigua—

1·9 grammes per 300 c.c.

No.	Minimum.	Maximum.	Average.
14	1/13	4/61	41·2
17	3/12	8/60	41·

Cosmophila sabulifera—

1·9 grammes per 300 c.c.

No. 10. Minimum 3/13. Maximum 3/36. Average 25·5.

Diacrisia obliqua—

0·95 gramme per 300 c.c.

No.	Minimum.	Maximum.	Average.	
20	5/6	4/30	17·2	26·5
20	2/7	2/79	35·8	

1·9 grammes per 300 c.c.

No.	Minimum.	Maximum.	Average.	
25	22/22	3/30	23	17·3
22	2/6	3/78	48	
10	8/6	2/30	10·8	

Marasmia trapezalis—

0·95 gramme per 300 c.c.

No.	Minimum.	Maximum.	Average.
21	9/44	2/86	35·3 } 41·5
16	11/31	5/85	47·8 }

1·9 grammes per 300 c.c.

No. 19. Minimum 3/6. Maximum 4/62. Average 33.

Acridium aeruginosum—

0·95 gramme per 300 c.c.

No.	Minimum.	Maximum.	Average.
3	1/54	2/80	..
3	1/36	1/72	1/196

As in other cases, the grasshopper simply declines food and waits; but the effect of this compound is fairly well marked.

Copper cyanide is clearly a violent poison, and is extremely interesting as being an insoluble cyanide, whose effect one might expect to be very good. The cyanides are, unfortunately, inadmissible in practice.

Napthalin.

There are two series of experiments here; in the first, the napthalin was not properly emulsified but was finely divided in water and its distribution on the leaf uneven; in the second an emulsion was formed but as this contains kerosine, size and soft soap, the results are not wholly attributable to napthalin. In both series the figures are not individually reliable.

Sylepta derogata—

0·5 gramme per 300 c.c.

No.	Minimum.	Maximum.	Average.
20	16/6	4/12	7·25
20	5/6	5/144	55
17	3/7	3/158	63

1·0 gramme per 300 c.c.

No.	Minimum.	Maximum.	Average.
19	16/6	3/12	7·0
18	7/6	2/78	42

2·0 grammes per 300 c. c.

No.	Minimum.	Maximum.	Average.
20	20/7	..	7
20	20/7	..	7
20	16/6	4/18	8·4

In the last series especially the napthalin separates out on the leaves in crystals and the caterpillars eat these and die very soon. The figures are probably valueless.

2·0 grammes in 300 c.c. spirit.

No.	Minimum.	Maximum.	Average.
20	20/12	..	12
10	4/6	2/36	16·8

Ten lived over and pupated, at intervals of 7 to 11 days and were apparently unaffected.

2·0 grammes with 4·0 grammes lac.

No. 18. Minimum 17/6. Maximum 1/12. Average 6.

Two pupated two days after.

No.	Minimum.	Maximum.	Average.
20	20/6	..	6
12	1/54	1/192	82·5

Eight pupated in 9 to 12 days.

The above series, done with one species, show how variable the apparent action is, due to errors of experiment purely. When napthalin in solid form was applied to the leaf they died quickly, or they survived indefinitely, owing to their no longer absorbing any napthalin. It is useless to give details of the long series of experiments made with all the species: the following are extracted at random:—

Ophiusa melicerte—

1·0 gramme per 300 c.c.

No. 6. Minimum 2/48. Maximum 1/168. Average 77·0.

Caradrina exiqua—

Napthalin 2·0 grammes. Lac 4·0 grammes per 300 c.c.

No. 17. Minimum 3/54. Maximum 1/160. Average 98.

Napthalin 2·0 grammes in 300 c.c. spirit.

No. 16. Minimum 12/78. Maximum 4/100. Average 94.

Pierid caterpillar—

No. 20. Minimum 1/15. Maximum 1/111. Average 63.

Acridium aeruginosum—

No.	Minimum.	Maximum.	Average.
3	1/168	1 in 12 days	1 in 19 days.
4	2/80	1 ,, 12 ,,	1 ,, 16 ,,

A series was done then with napthalin emulsion on *Diacrisia obliqua*—

No.	Minimum.	Maximum.	Average.
8	8/5	..	5
15	12/14	3/38	20
15	15/6	..	6
15	15/4	..	4
15	15/5	..	5

In this case the napthalin was thoroughly emulsified, the emulsion thoroughly mixed and the distribution on the leaf even. The killing effect may not be due wholly to napthalin. (*See* Appendix III.)

We here leave napthalin with the opinion that it is a first class insecticide, but as practical experience showed, too volatile to be of use except in special cases. (*See* Appendix III.)

Barium Chromate—

See remarks above on p. 286.

Lead Chromate—

See summary above on p. 286.

CALCIUM CYANAMIDE. Ca CN_2.

Sylepta derogata—

2·7 grammes per 300 c.c.

No.	Minimum.	Maximum.	Average.	
20	2/6	13/54	41·4	24
20	2/6	4/37	29·7	
20	3/6	12/37	26·3	
20	16/7	2/38	10·8	
19	8/6	2/25	11·4	

Caradrina exigua—

No. 13. Minimum 1/12. Maximum 6/60. Average 46.

Marasmia trapezalis—

No. 20. Minimum 1/6. Maximum 2/128. Average 72·6.

Ophiusa melicerte—

No. 20. Minimum 2/8, rest pupated in from 5 to 13 days.

Diacrisia obliqua—

No.	Minimum.	Maximum.	Average.
22	4/6	1/128	45·
20	2/6	13/54	41·4
20	2/6	4/37	29·7
20	3/6	12/37	26·3
20	16/7	2/38	10·8
19	8/6	2/25	11·4
20	1/6	2/128	72·6

Acridium aeruginosum—

No. 4. Minimum 3/30. Maximum 1/500.

The above were all experiments in the open; experiments were made on live plants in cages.

Ophiusa melicerte—

2·7 grammes in 300 c.c.

Two died in 6 hours, 6 lived and pupated after 5 to 13 days.

Diacrisia obliqua—

1 lb. to 12 gallons. ($2\frac{1}{2}$ lbs. used as the cyanamide is 40 per cent. pure). Thirty caterpillars, no results, the leaves not eaten and all turned brown. Done on castor and groundnut.

This compound seems to be effective if evenly applied, but undoubtedly burns foliage excessively. Its uneven action is probably explained by the compound, though finely ground, not being evenly distributed, the particles of the actual cyanamide not being properly diffused through the mass or in the water.

COPPER BORATE. $Cu\ B_4O_7$.

Caradrina exigua—

·6 gramme per 300 c.c.

No. 50. Minimum 3/21. Maximum 2/84. Average 50.

1·5 grammes per 300 c.c.

No.	Minimum.	Maximum.	Average.
41	4/15	4/84	52
12	1/7	3/54	36

3·7 grammes per 300 c.c.

No. 73. Minimum 5/6. Maximum 4/60. Average 40.

Anosia plexippus—

0·6 gramme per 300 c.c.

No. 7. Minimum 2/15. Maximum 2/66. Average 42.

1·5 grammes per 300 c.c.

No. 13. Minimum 3/20. Maximum 1/78. Average 44.

3·7 grammes per 300 c.c.

No. 70. Minimum 6/6. Maximum 4/63. Average 40.

Prodenia littoralis—

0·6 gramme per 300 c.c.

No. 10. Minimum 2/18. Maximum 2/90. Average 62.

1·5 grammes per 300 c.c.

No. 12. Minimum 1/6. Maximum 3/54. Average 36.

Ophiusa melicerte—

Half an ounce per gallon sprayed on castor plants—10 larvæ—2 died in 29 hours, 2 in 120, rest pupated.

Prior to the testing of dry paints, we regarded this as a very likely compound and we commend it to the notice of those who want an insoluble copper compound which is not really poisonous and is a good deterrent. A method of preparing it is given in Appendix IV; we believe that further work with this compound would prove it to be a very useful mild insecticide or deterrent.

COPPER SULPHIDE. Cu S.

Caradrina exigua :—

0·5 gramme per 300 c.c.

No.	Minimum.	Maximum.	Average.
12	1/42	4/78	64
18	3/30	1/78	50

1·5 grammes per 300 c.c.

No.	Minimum.	Maximum.	Average.
12	1/6	5/78	58
20	1/6	10/54	42
19	5/12	3/62	35·8
55	6/27	4/69	48

4·5 grammes per 300 c.c.

No.	Minimum.	Maximum.	Average.
18	9/9	4/54	26
16	3/6	9/30	23
20	2/18	6/56	41

Prodenia littoralis—

0·5 gramme per 300 c.c.

No. 20. Minimum 4/24. Maximum 1/60. Average 36·7.

1·6 grammes per 300 c.c.

No.	Minimum.	Maximum.	Average.
5	1/16	1/52	38
20	5/31	15/36	35

4·5 grammes per 300 c.c.

No. 20. Minimum 2/6. Maximum 1/78. Average 40.

Pierid—

0·5 gramme per 300 c.c.

No. 14. Minimum 1/44. Maximum 1/156. Average 91.

1·5 grammes per 300 c.c.

No. 13. Minimum 1/20. Maximum 1/156. Average 76.

4·5 grammes per 300 c.c.

No.	Minimum.	Maximum.	Average.
19	10/22	2/58	28
20	12/14	1/63	27·4

Anosia plexippus—

1·6 grammes per 300 c.c.

No. 6. Minimum 2/18. Maximum 1/78. Average 49.

4·5 grammes per 300 c.c.

No. 4. Minimum 2/12. Maximum 2/36. Average 24.

Ophiusa melicerte—

In the open on castor, at ½ oz. per gallon, of 6 none died, of 10 2 died in 4 days, the rest survived and pupated.

In the open on castor, 1 oz. per gallon, of 10 none died, the leaves were eaten, they all pupated.

Copper sulphide is apparently of little value in small doses, a strength of somewhere near 1 lb. to 10 gallons very well applied being required to have any effect. It is a deterrent but as an insecticide,

good Bordeaux mixture would probably be far more effective and lasting. Its use as a powder deterrent is indicated.

BORAX. $Na_2 B_4 O_7 \quad 10 H_2 O$.

Caradrina exigua—

1·0 gramme per 300 c.c. No effect.

3·1 grammes per 300 c.c.

No.	Minimum.	Maximum.	Average.
18	2/12	1/111	41
16	1/8	1/108	38
17	4/5	4/120	45
16	6/6	2/136	57

Prodenia littoralis—

3·1 grammes.

No. 9. Minimum 2/19. Maximum 1/79. Average 36.

Anosia plexippus—

3·1 grammes.

They died after 2 days or more, leaving the food practically untouched; 3 trials were made with 29 larvæ, but the results were the same in each.

No.	Minimum.	Maximum.	Average.
11	1/30	1/72	42
8	2/43	2/63	52
10	1/24	1/72	55

Sprayed on to castor plants, at ½ oz. per gallon, it had little effect—2 died in 24 hours, 1 in 120 hours, 17 pupated; at 1 oz. the figures were 6/72, 4/90, 1/96, 1/120 1/132, 2/156, 2/200 : 3 pupated.

Borax is of interest as being one of the very few compounds used as an insecticide for Blattids, which is neither an arsenical nor an alkaloid; a one per cent. solution is a fairly effective stomach poison and a good deterrent, but the Sodium salt cannot of course be used in general practice; and the insoluble borates have less action than this one, with the exception of the copper salt above mentioned.

Boracic Acid. $B(OH)_3$.

Prodenia littoralis—

2·1 grammes per 300 c.c.

No. 8. Minimum 6/30. Maximum 1/54. Average 35.

Caradrina exigua—

2·1 grammes per 300 c.c.

No.	Minimum.	Maximum.	Average.
17	1/15	3/92	56
38	2/24	4/75	50

Anosia plexippus—

2·1 grammes per 300 c.c.

They totally declined food and died of starvation in from one to three days.

Boracic acid at this strength is clearly a deterrent and a poison of the second class. It cannot of course be used practically. Its poisoning action like that of borax may be due to the fact that insects feeding normally on leaves of whatever kind never meet with it and so are totally unused to it.

LEAD OXIDE. (RED LEAD). $Pb_3 O_4$.

Caradrina exigua—

3·7 grammes per 300 c.c.

No. 50. Minimum 4/7. Maximum 6/66. Average 41.

Prodenia littoralis—

3·7 grammes per 300 c.c.

No. 9. Minimum 1/16. Maximum 1/76. Average 44.

Anosia plexippus—

No. 13. Minimum 3/24. Maximum 1/57. Average 36.

These figures are curiously uniform and clearly put Red lead in class 2, as a valuable insecticide ; it is good for its other qualities as well, such as cheapness, availability, insolubility and the like.

LEAD SULPHIDE. Pb S.

Prodenia littoralis—

4·0 grammes per 300 c.c.

No.	Minimum.	Maximum.	Average.
4	1/36	2/60	51
4	1/48	1/90	69·5

Anosia plexippus—

No. 10. Minimum 2/16. Maximum 1/72. Average 37·8.

Caradrina exigua—

No.	Minimum.	Maximum.	Average.
13	1/36	1/150	77·5
15	4/30	1/54	40·
11	1/6	3/90	52·4
10	9/9	1/21	10·2
9	4/20	2/48	30·2

This compound appears to be similar in its effects to Lead oxide (Red lead). As the sulphide would have to be used in its precipitated form, the oxide would probably be cheaper and more convenient.

LEAD BORATE. $Pb B_4 O_7$.

Caradrina exigua—

1·0 gramme per 300 c.c.

No.	Minimum.	Maximum.	Average.
4	1/78	1/94	84·5
12	1/42	1/96	76

It might have been expected that this compound would have proved at least as efficient as Lead oxide, if only because Boric acid gave such decidedly favourable results. The above figures for Lead borate are distinctly worse than those for either Boric Acid or for Lead oxide.

LEAD CARBONATE. $Pb Co_3$.

Caradrina exigua—

4·38 grammes per 300 c.c.

No. 12. Minimum 1/36. Maximum 1/126. Average 78.

See also " White Lead " page 285.

BARIUM PEROXIDE.

Caradrina exigua—

2·8 grammes per 300 c.c.

No effect. The larvæ (18) lived up to a week and then pupated.

BARIUM CARBONATE—

Caradrina exigua—

No effect.

The results contrast rather strongly with those obtained from Barium oxalate and Barium borate, *vide* below. The latter compounds, while variable in their effects, gave indications of a considerably higher killing power. It is probable that the latter is rather a measure of the respective powers of Boric and Oxalic acids than of that of Barium.

BARIUM OXALATE.

Caradrina exigua—

4·1 grammes per 300 c.c.

In the first trial with 4 caterpillars, the following results were obtained :—

1 died in 6 hours.		
4 „ „ 42 „		average killing power—40.
1 „ „ 72 „		

but in a subsequent trial with 12 caterpillars only 2 died in 3 days and the rest pupated.

It would appear therefore that the effect of Barium oxalate, while distinctly good in some cases, is not sufficiently constant to be depended on even at the great strength of 1 lb. in 7 gallons.

BARIUM BORATE. $B_a B_4 O_7$.

(*a*) At a strength of 0·6 gramme per 300 c.c. and 1 lb. in 50 gallons, this compound was without effect.

(*b*) At a strength of about 1 lb. in 10 gallons one experiment gave an average killing period of 35 hours and a second one of 50 hours. In a third experiment however, out of 15 caterpillars, only one had died in 36 hours when the experiment was stopped.

These results vary amongst themselves to such an extent as to render further trials advisable ; but judging from the figures for other compounds of Barium, it is not probable that Barium borate would, at reasonable strength, prove to have a powerful insecticidal effect.

ZINC OXIDE. $Zn O$.

Caradrina exigua—

1·3 grammes per 300 c.c.

The mean of six experiments at the above strength with this compound gave an average killing power of 52 with extremes of 84 and 27.

While the extreme figures would place Zinc oxide low in the scale of possible insecticides, the low figures, of which there were two below 40, make it, on account of its cheapness, well worth further investigation.

Zinc sulphide. 1·5 grms. per 300 c.c. ZnS.—

At the above strength Zinc sulphide was quite ineffective with (*a*) larvæ of *C. exigua*, (*b*) Pierid caterpillar on Bagnai.

OXIDE OF IRON. (1 lb. in 16 gallons).

Diacrisia obliqua—

The following are the results with this compound :—

20. 1/96 4/120 2/144·13 pupated. Average 1·123.

All the food given to the caterpillars was eaten, and Oxide of iron is obviously quite harmless.

BURNT SIENNA—

See results on p. 285.

BURNT UMBER—

See results on p. 285.

PRUSSIAN BLUE—

See results on p. 285.

YELLOW OCHRE—

See results on p. 285.

ULTRAMARINE BLUE—

See results on p. 285.

LEMON CHROME—

See results on p. 285.

CHROME ALUM—5·5 grammes in 300 c.c.

(*a*) Pierid caterpillar on *Copparis.*

(*b*) Larvæ of *Caradrina exigua.*

This compound proved to be harmless as no deaths took place within 5 days.

ALUM—5·0 grammes in 300 c.c.

Pierid caterpillar on *Copparis.*

At the above strength, the killing power of this compound was only 115. It is therefore useless.

MAGNESIUM OXIDE—

Had no effect at all.

MAGNESIUM CARBONATE—

No effect.

MAGNESIUM SULPHATE. 4·1 grammes in 300 c.c.

(*a*) *Caradrina exigua*—

This compound appears to have a much more powerful effect than either the Oxide or the Carbonate, for out of 20 caterpillars 11 died in an average of 45 hours. Even on this result however Magnesium sulphate would only come into class III. Its solubility, of course, would prevent its being used in practice; but it might be worth while trying the effect of a Magnesium borate or of Magnesium oxalate.

(*b*) *Sylepta.* No effect.

STANNOUS CHLORIDE. 3·1 grammes per 300 c.c.

Caradrina exigua—

Three died in 36 hours, two in 60, the rest (12) were unaffected.

Sylepta derogata—

No effect.

SODIUM CARBONATE. 4·4 grammes per 300 c.c.

Caradrina exigua—

The average killing power, in one experiment, of this compound was, 51; probably due to its caustic properties. The latter however as well as its solubility prevent its being considered as a practical insecticide, even if its killing power was sufficiently great.

POTASSIUM CHLORIDE. K Cl. 2·5 grammes per 300 c.c.

(*a*) *Caradrina exigua*—

With this compound, in one experiment—

3 caterpillars died in 24 hours.
4 more ,, ,, 30 ,,
4 ,, ,, ,, 54 ,,

Its average killing power was therefore 37 ; a fairly good result ; but the compound is not, on account of its solubility, a possible insecticide.

Sylepta derogata—

No effect.

COPPER TANNATE—

2 grammes of $Cu\,S\,O_4, 5\,H_2\,O$ in 300 c.c.
4 ,, ,, Tannic Acid ,, ,, ,,

Prodenia littoralis—

No. 20. Minimum 1/48. Maximum 5/144. Average 112.

It is interesting to compare this with Lead Tannate, which is distinctly class IV. One would not perhaps expect Tannates or Tannic Acid at all to affect insects and the action may be due solely to the metallic salt.

LEAD TANNATE. 7 grammes in 300 c.c.

4 grammes Lead Acetate.
3 ,, Tannic Acid.

Prodenia littoralis—

This compound was found to be incapable of killing more than 8 out of 20 caterpillars in 5 days. It is therefore much less powerful than Copper Tannate. The figures were—

20 larvæ.
2 died in 96 hours.
1 ,, ,, 100 ,,
1 ,, ,, 108 ,,
1 ,, ,, 120 ,,
3 ,, ,, 144 ,,
6 pupated.
2 more pupated.
4 failed to pupate.
6 moths emerged.
2 ,, failed to emerge.

MANGANESE DIOXIDE. $Mn O_2$.

No result.

IRON SULPHIDE. Fe S.

No result.

PHENYL HYDRAZINE HYDROCHLORIDE. 1·8 grammes in 300 c.c.

Caradrina exigua—

No. 20. 2/30, 6/60, 12 unaffected.

Sylepta derogata—

No. 20. Minimum 1/6. Maximum 7/48. Average 27·3.

Diacrisia obliqua—

No. 10. Minimum 2/85. Maximum 1/240. Average 140.

ACETAMIDE. 2·0 grammes in 300 c.c.

Caradrina exigua—

20. Minimum 1/30. Maximum 6/60. Average = 55. 10 caterpillars left unkilled.

METAPHENYLENE DIAMINE HYDROCHLORIDE. 2·4 grammes in 300 c.c.

Caradrina exigua—

No. 20. 3/30, 2/54, 2/60, 11 unaffected.

This compound had no effect on the Cotton leaf-roller.

POTASSIUM FERROCYANIDE. 2·0 grammes in 300 c.c.

Sylepta derogata—

No effect.

Caradrina exigua—

No. 20. 1/24, 3/36, 6/60, 9 left.

It appears from this and from results obtained for other compounds that *C. exigua* is much more easily affected than the Cotton leaf-roller.

POTASSIUM FERRICYANIDE. 1·8 grammes in 300 c.c.

Sylepta derogata—

No effect.

Caradrina exigua—

No. 20. 2/36, 5/60, 12 left.

This result corresponds very closely with that for Potassium ferrocyanide. Neither is sufficiently good to render it an efficient insecticide, even if its solubility were not a bar to its use.

PICRIC ACID. 2·5 grammes in 300 c.c.

Sylepta derogata—

No effect.

Caradina exigua—

No. 20. 1/24, 3/36, 5/60, 10 left.

POTASSIUM BICHROMATE. 1·6 grammes in 300 c.c.

Sylepta derogata—

No effect.

Caradrina exigua—

No. 20. 3/36, 5/60, 2 parasitised, 10 left.

Morphine. 0·3 grammes in 300 c.c.

At the above strength, no appreciable effect was produced in *Sylepta derogata.*

AMMONIUM PERSULPHATE. 1·0 grammes in 300 c.c.

Sylepta derogata—

With very large specimens in one experiment no effect was produced. In a second trial with smaller caterpillars the following results were obtained :—

20—1/6, 6/36, 5/60, 1/72, 2/84 = 50.

Caradrina exigua—

1st trial :—20—13/12, 2/22, 1/24, 2/36, 1/52, 1/96 = 22.

2nd trial :—20—1/6, 2/30, 7/54, 9 left.

Judging by its effect both on *Sylepta* and *Caradrina*, Ammonium persulphate is a fairly powerful insecticide and it would appear that the effect of insoluble compounds of this acid might be worth investigating.

Sodium benzoate. 4·8 grammes in 300 c.c.

No appreciable effect on either the Pierid caterpillar or on *Caradrina exigua.*

CAFFEIN. 0·3 gramme in 300 c.c.

Caffein was found to be quite ineffective with *Sylepta*.

Sodium tartrate. 3·8 grammes in 300 c.c.
No action on Pierid caterpillar or on *C. exigua*.

TARTARIC ACID. 2·5 grammes in 300 c.c.
No action on *C. exigua*.

SULPHUR. 0·5 gramme in 300 c.c.
No action on Pierid caterpillar or on *C. exigua*.

QUININE. 5 grammes in 300 c.c.
No appreciable action on the Pierid caterpillar or on *Caradrina exigua*.

CARBOLIC ACID. 3·0 grammes in 300 c.c.
Had no effect on Pierid caterpillar or on *C. exigua*.

SODIUM SUCCINATE. 2·8 grammes in 300 c.c.
No appreciable effect on Pierid caterpillar.

TANNIC ACID. 3·0 grammes in 300 c.c.
No effect on Pierid caterpillar.

GALLIC ACID.
No effect.

LAC. 4·0 grammes in 300 c.c.

Sylepta derogata—
20—5/7, 4/38, 8/14, 1/24, 2/26 = 1[illegible]·75.

Diacrisia obliqua—
10—2/78, 2/126, 2/174, 1/198 = 136.

Lac thus proved to have a powerful killing effect on *Sylepta derogata* which is particularly resistant to many other inordinate poisons.

In the case of *Diacrisia obliqua*, its actual killing power is very low according to the figures; but for 3 whole days, the caterpillars refused to eat the lac-treated leaves; lac, in this case, appears to have acted as a very effective preventive.

On the whole it would appear that lac has sufficient possibilities as a preventive to justify further trials.

CHLORAL HYDRATE. 2·75 grammes in 300 c.c.

Sylepta derogata—

Practically no effect.

Caradrina exigua—

(1) 20—11/13, 1/23, 1/24, 2/36, 2/60, 2/70, 1/147 = 34.

(2)—20. None died in 48 hours.

The above results do not indicate that this substance has any probable value.

STRYCHNINE. 0·3 gramme in 300 c.c.

Caradrina exigua—

14—4/18, 3/30, 2/54, 5/78 = 46.

Pierid caterpillar—

(1) 20—1/6, 11/15, 1/24, 7/31 = 21.

(2) 19—2/5, 4/8, 9/38, 3/50, 1/56 = 31.

Sylepta derogata—

10—3/12, 1/24, 3/36 = 16·8.

In this case 20 caterpillars were put into the cage but the experiment was stopped after 48 hours.

The general effect of the small amount of Strychnine used, 1 lb. in 100 gallons, shows that its effect is a powerful one. In the case of the Pierid caterpillars the whole number put in were moribund in 8 hours. The price of pure Strychnine would be prohibitive; but it is possible that a crude preparation might be sufficiently cheap to allow of its being used economically.

BRUCINE. 0·3 gramme in 300 c.c.

Sylepta derogata—

(1) 14—2/24, 4/60, 3/72, 5/84 = 66.

(2) 20. None died in 48 hours although leaves were eaten. Brucine is therefore far less powerful in its action than Strychnine.

SACCHARIN. 2·0 grammes in 300 c.c.

Sylepta derogata—

17—2/12, 1/56 = 58·7

6/14, 2/38, 2/86, 1/132 = 1/180.

It is obvious from the above figures that Saccharin does not offer any possibilities of useful application.

POTASSIUM IODIDE. 5·5 grammes in 300 c.c.

(*a*) *Cotton Leaf-roller*—

No effect.

(*b*) *Caradrina exigua*—

26—2/24, 3/36, 3/60, 13 left.

(*c*) *Sylepta derogata*—

No effect.

Potassium Iodide has therefore no marked action.

PART III.

The series of experiments above described are all on captive insects fed on picked food, not on the growing plant or free to wander. What actually happens in field spraying? Do the caterpillars feed and die, do they feed, get ill and wander away or what happens? From observation of sprayed crops, we believe that both the above occur, but that with some poisons death occurs fairly soon as the insects do not perceive the poison, in others the poison is either tasted or makes them unwell and they then wander, seeking unsprayed food and are gradually poisoned, are starved or are destroyed by birds since they wander off the plants. This can be well illustrated by feeding caterpillars on plants growing in the open under cages. In one instance, *Diacrisia* were feeding on the wild nettle; a clump was sprayed with Lead Chromate in water and a cage put over, large larvæ of *Diacrisia* were then put in; they fed a little here and there but not normally; they wandered about the cage; they remained alive for several days and actually managed to eat into the succulent stems and feed on the unsprayed tissue; they became boring larvæ to some extent, a habit they never show normally and but for being incommoded by their dense covering of hairs they would possibly have gone completely inside. This illustrates very well the deterrent action of Lead Chromate and this action is not confined to this compound. The action of Naphthalin is discussed below in Appendix III.

It would appear that one can think of stomach poisons in two ways; there are those which are unperceived poisons, the insect absorbing a lethal dose before the effects manifest themselves (either on account of the virulence of the poison or of its not producing irritant symptoms); there are those which are less poisonous but which either produce irritant symptoms or are perceived, rendering the food-plant distasteful. Which action an individual

compound has, depends to some extent on the caterpillar used, but if one tests compounds on one caterpillar throughout, one sees very marked differences in the way the poisoned food is taken. On the other hand different kinds of caterpillars shew marked difference in resistant power to the same poison.

Speaking generally the most marked "deterrent" action was that of Lead Chromate; perhaps the least was the Lead Arseniate itself but all in class I come under the category of poisons and not of deterrents. The classes into which we divide our compounds are therefore not based wholly upon actual poisoning effects; a marked deterrent action slows the action of the poison very much, giving it a higher lethal figure; in practice therefore we have to select from classes I & II together.

The practical outcome of all these experiments has been the selection of Lead Chromate as a standard stomach poison to replace arsenical poisons; and the selection of certain available dry paints which are recommended for application as deterrents on young crops. An article describing the use of Lead Chromate as an insecticide was published in the Agricultural Journal of India (Vol. V, p. 138). An extract from this is appended (Appendix II). Its use has also been described in Bulletin No. 23, Agric. Res. Inst., Pusa, on insecticides. It is available as a powder, pure or at strengths of 33% or 50%, and as a paste containing 66% of Lead Chromate. It may also be prepared from Potassium Bichromate and Lead Nitrate or Lead Acetate.

The further outcome has been the use of "dry paints" as deterrents particularly on young crops; the following are available in India at the approximate indicated prices:

Lead Chromate ..	Lemon Chrome	As. 6 to 12 as. per lb.
Lead Oxide ..	Red Lead	Rs. 23 per cwt.
Lead Carbonate ..	White Lead	„ 24 „
Iron Oxides ..	Oxide of Iron	„ 14 „
„ „ ..	Yellow Ochre	„ 14 „
„ „ ..	Red Ochre	„ 14 „
„ „ ..	Burnt Sienna	As. 12 lb.
Iron and Manganese	Burnt Amber	„ 7 „
Zinc and Cobalt Sulphide.	Saxon Green	„ 6 „

These are used for dusting particularly on young crops, such as cereals, tobacco, cotton, etc., which are attacked by grasshoppers and surface weevils.

The experiments have also brought out the value, as a stomach poison, of Naphthaline Emulsion. The great advantage is its volatility, so that green plants intended for consumption can be safely sprayed when mature. Its preparation is dealt with in Appendix III.

Although the experiments now described have been very numerous, the work can only be regarded as a more or less rough preliminary to a much more thorough investigation of individual compounds which have given indications of possible utility. In addition to those already mentioned in this summary, we would draw attention to the following :—

Lead Oxide.
Lead Sulphide.
Copper Oxide.
Copper Sulphide.
Borates.
Oxalates.
Phenyl Hydrazine Compounds.
Barium Compounds.
Lac.
Zinc Oxide.

APPENDIX I.

The insects used as subjects in this investigation are the following :—

Caradrina exigua, Hübn. A common caterpillar, with a large range of foodplants, feeding on indigo, lucerne, maize, cotton, safflower, gram, and a number of weeds. A full account of it has been published. (Agricultural Journal of India, Vol. I, p. 338 [1906]).

Prodenia littoralis, Boisd. Another common caterpillar, with a still larger range of foodplants, including tobacco, indigo, lucerne, cabbage, castor, jute, potato, mulberry, etc. A full account of it has been published. (Memoirs of the Department of Agriculture in India, Entomological Series, Vol. II, No. 5 [1908]).

Ophiusa melicerte, Dr. The semi-looping caterpillar of the castor plant, known to feed also on *Euphorbia pilulifera*. A full account has been published. (Memoirs of the Department of Agriculture in India, Entomological Series, Vol. II, No. 4 [1908]).

Anapheis mesentina, Cram. Referred to as the "Pierid." A common caterpillar feeding upon *Capparis horrida* (Bagnai).

Marasmia trapezalis, Guen. The Maize Leaf-roller. A Pyralid common on maize.

Diacrisia obliqua, Wlk. The Behar Hairy Caterpillar; an Arctiid which is extremely omnivorous and abundant.

Sylepta derogata, Fabr. The Cotton Leaf-roller. It has a range of foodplants in the *Malvaceæ* chiefly. A full account has been published. (Memoirs of the Department of Agriculture in India, Entomological Series, Vol. II, No. 6 [1908]).

Anosia (*Danais*) *chrysippus*, Linn. Feeds on *Calotropis* spp.

Cosmophila sabulifera, Wlk. The Jute Semi-looper. An account

has been published. (Agricultural Journal of India, Vol. II, p. 109 [1907]).

Acridium aeruginosum, Burm. (*Cyrtacanthacris ravacca*, Stoll.). The Black Spotted Grasshopper. Feeds on cotton. (Indian Insect Life, p. 86).

APPENDIX II.

Having defined classes I and II, the practical necessities of the case were considered; for instance, Iodoform is very deadly, but useless as a field insecticide. We therefore turned to the substances in classes I and II that might be useful, and we found that some of them might be commercially available. What are the conditions which an insecticide must fulfil? It must be (*a*) insoluble in water or rain washes it off; (*b*) cheap and easily available; (*c*) stable and not apt to decompose into compounds that poison the leaf.

Eliminating from classes I and II the compounds not fulfilling these conditions, there remained a small number of substances, not of very high killing value, that might be valuable as "deterrents" if not as "insecticides." Thus, a plant sprayed with Copper Sulphide might be so distasteful to caterpillars that they would leave it even if it did not poison them. The commercial possibilities of these were investigated, and it was found some of them were available as dry paints; these were tested, and among them was a particularly effective compound sold as Lemon Chrome; this consists of Gypsum and Lead Chromate in particular proportions to give a lemon yellow tint. Lead Chromate was accordingly tested and gave good results; its poisoning action was high, and it seemed likely to be a commercial possibility. Up to now all the tests were insectary ones; field tests were then made, first on plants under control with a definite number of caterpillars on; then, as opportunity offered, on crops attacked by caterpillars. On these field tests, it was found that some otherwise suitable compounds injured the plants, and as a result of these tests, all other compounds but Lead Chromate were, for the present, abandoned. Lead Chromate offers distinct advantages; it is easily made in paste form; it is yellow and can be easily seen on a sprayed plant; it is extremely insoluble; soluble chromates

do not poison plants to the extent arsenic does, so even were it to decompose, it would not be injurious; it does not decompose on a leaf; it is not easily washed off; it contains no arsenic. During this year we have applied this compound to a great variety of crops; we have sprayed them till every leaf was yellow; the poison has remained on for over three weeks, thickly on the leaves, which were uninjured; sprayed on to crops attacked by caterpillars, the caterpillars are killed, and the results obtained have been excellent. We have used this at 1 lb. in 32 gallons; at this strength it is entirely safe, poisons caterpillars and acts as a very powerful deterrent.

In protecting plants from caterpillars and grasshoppers there are two things to consider: are you dealing with a caterpillar which feeds specially on that plant, or are you dealing with a grasshopper or beetle which is not restricted to that plant? For the former you must apply an insecticide, a real killing agent, that will poison it, because it can feed on nothing but that plant, and all its instincts are to do so; for the latter, a deterrent is sufficient, because it will leave that sprayed crop and go elsewhere. In certain cases a deterrent is sufficient; in others, especially with caterpillars, you must apply a really deadly compound in small amounts that will actually kill. Lead Chromate has not the poisoning effect of Paris Green for instance, which can be applied at one pound in 200 gallons; but it has a poisoning effect comparable with that of Lead Arseniate and is, in our experience, a perfect substitute.

Lead Chromate is made by dissolving in one lot of water Potassium Bichromate, in another lot of water Lead Acetate or Nitrate. The two solutions are mixed, and a dense yellow precipitate of insoluble Lead Chromate is formed, and Potassium Nitrate or Acetate. The latter is soluble and is readily washed out of the precipitate. We have neglected it and prepared our Lead Chromate by dissolving the Lead Salt in the spraying machine, dissolving separately the Bichromate and adding the solution to the spraying machine. The figures are as follows:—

66·2 grammes of Lead Nitrate combined with 29·4 grammes of Potassium Bichromate giving 64·6 grammes of Lead Chromate

allowing for impurities, we found that 65·2 grammes of commercial Lead Nitrate combined with 30 grammes of Potassium Bichromate; in practice 2 ounces of Lead Nitrate combined with one ounce of Potassium Bichromate giving two ounces of Lead Chromate; this is the actual amount required for one kerosene tin of water (4 gallons) at full strength or for two kerosene tins of water at the usual strength.

This is the best way to apply it, to mix the two solutions in the spraying machine and then apply it; but the paste can be purchased and arrangements have been made for the sale of this insecticide.

In India, there is a very large field for the use of insecticides, but they are as yet very little known. For many reasons they cannot be applied at present to ordinary field crops; but from experiment farms, from those cultivating valuable crops, fruit trees, or vegetables we get a steady stream of enquiries as to how to check beetles, grasshoppers, caterpillars and similar biting insects. To all these there is but one answer: apply a stomach poison: now that a non-arsenical stomach poison is available, and that a thoroughly good reliable hand sprayer can be bought at a reasonable price in India, there is no reason why such pests should not be dealt with. At Pusa we have occasion to use stomach poisons constantly; against all insects that injure crops by biting the leaves, we use Lead Chromate and we can use no other method that is equally effective and cheap. The discovery of a substitute for arsenic removes one objection to this method of treatment, and we believe that there is no reason why the use of this insecticide should not entirely remove the losses experienced from this class of pest on the more valuable crops and on experiment farms. There is at present no commercial agency that advertises and pushes the sale of insecticides and machines, but we have arranged for the sale of this insecticide and will give particulars on application. (Agricultural Journal of India, Vol. V, p. 138, " A New Insecticide.")

APPENDIX III.

PREPARATION OF NAPHTHALENE EMULSION.

" Dissolve 6 oz. size (Patna sirish) in $\frac{1}{2}$ gallon water ; into this stir 1 lb. of soft soap. Dissolve 1 lb. of naphthalene in 1 gallon of kerosene. Mix the two solutions at once, and add another half gallon of water. The size-soap solution must be as hot as possible and the mixture must be well agitated while mixing."

In actual practice, we tried varying amounts of naphthalene ; as this is the active ingredient, it is desirable to have as much of it as possible ; by warming the oil, more naphthalene is dissolved and it was found that the emulsion came successfully in every case. Two, four, six and eight pounds of naphthalene were dissolved in the kerosene by warming for 6 lbs. the oil was heated to 123°F. (43°C.), for 8 lbs. to 140°F. (58°C.) ; the temperature required for 8 pounds is as high as is safe in actual practice with ordinary heating over hot water or a fire.

Using 7 lbs. of Naphthalene the cost is :—

6 oz. Size	2 as.
1 lb. Soft Soap	2 ,,
1 gallon Kerosene	14 ,,
7 lbs. Naphthalene	16 ,,
Rs. ..	2-2-0.

Using this at 5 lbs. of Naphthalene to 100 gallons makes the cost per 100 gallons about Re. 1-14-0.

At this strength, the mixture was tested on Castor for *Ophiusa melicerte*, and *Prodenia littoralis*, half the field being sprayed with Lead Arseniate at the same strength as a check. The concentrated

emulsion of Naphthalene mixes well with water, no separation taking place ; it keeps well and there was no difficulty in application. The action was very curious ; the plants were swarming with the caterpillars and were well sprayed with Knapsack sprayers. The immediate effect of the Napthalene was to make the caterpillars restless ; they moved about seeking unsprayed leaves ; they bored into the soft stems ; the young ones died, the mature ones became sick ; for one day all feeding practically ceased and the caterpillars were all moving ; but next day, after a day of hot sunshine (temperature in the shade 95°F.), the plants were free of naphthalene ; the caterpillers still in the field were feeding again ; there was no smell of naphthalene and the destruction recommenced.

The half sprayed with Lead Arseniate gradually became clear of caterpillars ; they died largely, though some moved away, but on the whole the action seemed to be one of direct poisoning. In three days it was clear and remained clear. The field was sprayed throughout at the same time and there was no space between the two halves.

Naphthalene applied in this way has no poisoning effect on any but small caterpillars ; it has a deterrent effect and it is as a harmless deterrent, which will have evaporated in a day or two days that it is valuable as an insecticide. It is used on vegetable crops intended for consumption with great effect and it is useless as a field insecticide.

APPENDIX IV.

Preparation of Copper Borate on a large scale for field use.

As the composition of Copper Borate is stated to be uncertain and no really definite information could be found concerning it: a few experiments were performed to see if the preparation of Copper Borate by double decomposition from Copper Sulphate and Sodium Borate follow the equation :—

$$Cu\,So_4.\,5\,Aq + Na_2\,B_4\,O_7\cdot 10Aq = Cu\,B_4\,O_7 + Na_2\,So_4 + 15Aq.$$

Solutions of Copper Sulphate (5%) and Borax (3·852 grammes per 100 c.c.) were made up, and portions of the one added to the other until no further precipitation took place and Potassium Ferrocyanide did not show its well-known reaction with Copper (a brown colouration) with a drop of the solution.

The reaction between the Borax and Copper Sulphate was found to be unsatisfactory; if the Copper solution be added to the Borax solution, constant results are obtained, but different though equally constant results are obtained if the Borax solution is added to the Copper solution. Thus when Copper was added to the borax, it was found that 1 c.c. of Borax solution was equivalent to 0·58 c.c. Copper solution, while when the Borax solution was added to the Copper solution it was found that 1 c.c. of Borax solution was equivalent to 0·68 c.c. of Copper sulphate solution.

As it is advisable to have the borax solution in slight excess, or in other words to precipitate all the copper it was decided to take

the first named figure, *i.e.*, 1 c.c. of Borax solution = 0·58 c.c. of $CuSo_4$ solution. From this :—

0·03852 gramme Borax = 0·029 gramme $CuSo_4$.

or, roughly :—

4 of Borax = 3 of $CuSo_4$.

Preparation of the Spraying mixture.

From 6 parts of Borax and 5 parts of Copper Sulphate
4½ parts of Copper Borate are obtained.
You want 0·5%, *i.e.*, 1 lb. in 20 gallons.
·2 ,, ,, 4 ,,
·38 lbs. of Borax and ·25 of $CuSo_4$ = ·2 of Copper Borate.
6 oz. ,, ,, ,, 4 oz. ,, = ·3 ,, ,, ,,
or one charge of the 4-gallon machine.

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THE LIFE-HISTORY OF *PSYLLA ISITIS* BUCKT. (*PSYLLOPA PUNCTIPENNIS*, CRAWFORD) THE "PSYLLA" DISEASE OF INDIGO

BY

A. J. GROVE, M.Sc

Officiating Imperial Entomologist

AND

C. C. GHOSH, B.A

Assistant to the Imperial Entomologist

AGRICULTURAL RESEARCH INSTITUTE, PUSA

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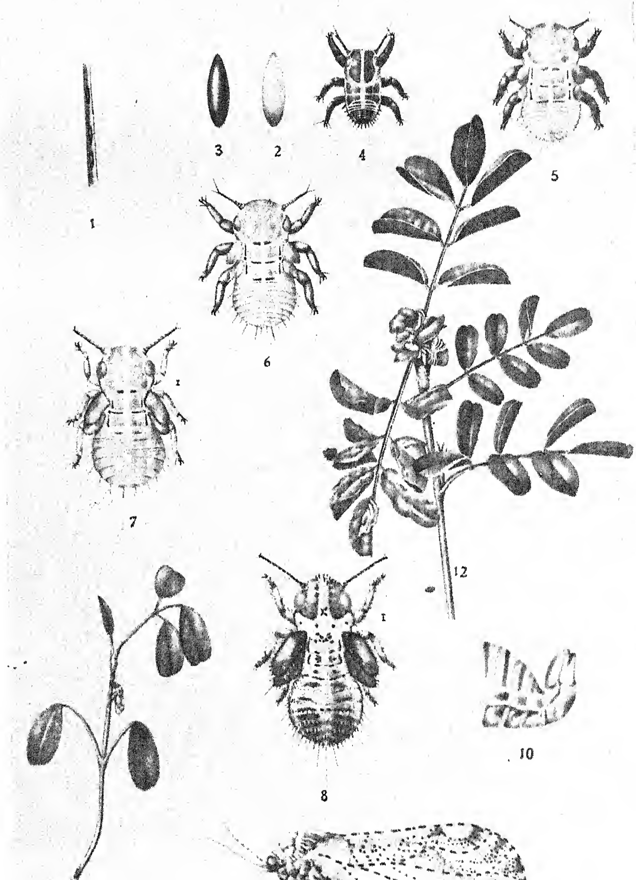
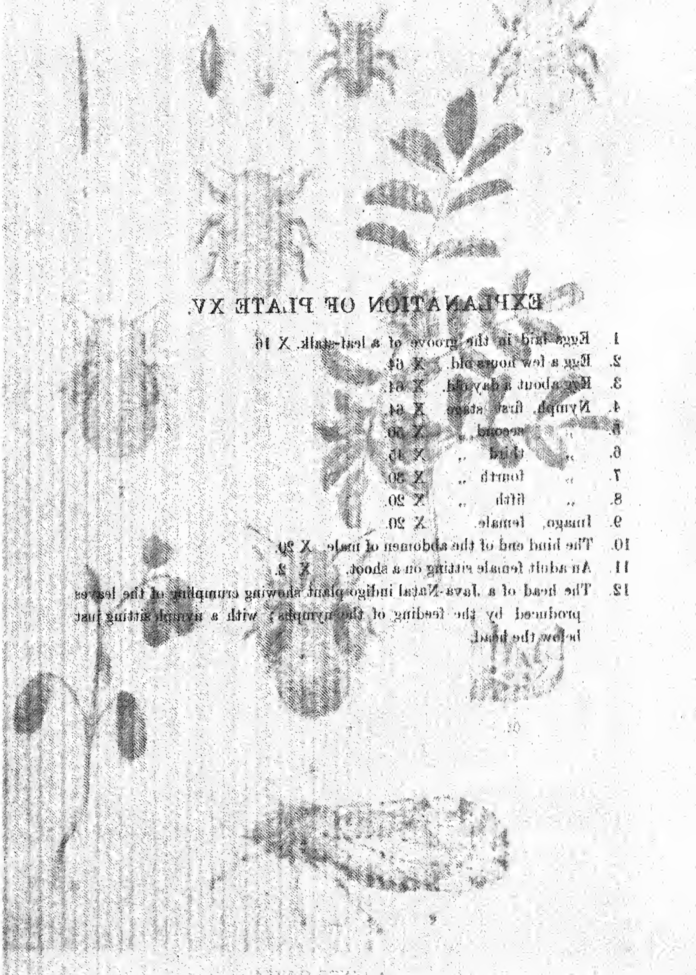


INDIGO PSYLLA.

EXPLANATION OF PLATE XV.

1. Eggs laid in the groove of a leafstalk. X 16.
2. Egg a few hours old. X 64.
3. Egg about a day old. X 64.
4. Nymph, first stage. X 64.
5. " second " X 50.
6. " third " X 45.
7. " fourth " X 30.
8. " fifth " X 20.
9. Imago, female. X 20.
10. The hind end of the abdomen of male. X 20.
11. An adult female sitting on a shoot. X 2.
12. The head of a Java-Natal indigo plant showing crumpling of the leaves produced by the feeding of the nymphs; with a nymph sitting just below the head.



PREFACE.

The observations included in this Memoir were made in connection with the investigation into the pests of Indigo in Behar which was taken up at the request of the Behar Planters' Association in December 1911. A general account of the pest and its relation to other diseases of Indigo was published by Mr. H. Maxwell-Lefroy, the former Imperial Entomologist, in the Agricultural Journal of India, Vol. VIII, Part 1, and the details of more scientific interest are included in this Memoir. This number will complete Vol. IV.

PUSA,
November 21*st*, 1913.

A. J. GROVE,
Offg. Imperial Entomologist.

THE LIFE-HISTORY OF *PSYLLA ISITIS* BUCKT. (*PSYLLOPA PUNCTIPENNIS*, CRAWFORD). THE "PSYLLA" DISEASE OF INDIGO

BY

A. J. GROVE, M. Sc

Officiating Imperial Entomologist

AND

C. C. GHOSH, B. A

Assistant to the Imperial Entomologist.

INTRODUCTION.

The pest of the indigo plant which has become known in Behar as Indigo "Psylla" is accountable for a great deal of damage to the indigo crop, though as has been stated by Lefroy (Agric. Journ. India, Vol. VIII, pt. 1), it cannot be held entirely responsible for the failure, especially of the *khoontie* crop, in recent years.

A Psyllid attacking indigo was first described by Buckton (Indian Museum Notes, Vol. II, page 18), but in the account given by Cotes it is stated: "The indigo shoots were found covered with minute black scales each containing a partially developed Homopterous insect, which was at first supposed to be one of the Aphidæ, but which has since been described by Mr. G. B. Buckton as a pupa of a new species of Psyllidæ, which he names *Psylla isitis*." These black scales were probably an Aleyrodid which is common on indigo and had no connection with the Psyllid. On page 167 of the same volume of Indian Museum Notes, *Psylla isitis* is put down as "a minute insect, which forms galls on indigo (*Indigofera tinctoria*) plants. It was reported in 1896 as excessively destructive to indigo in Bengal." Here, again, the hard knot of curled leaves produced by the attack of the insects has probably been

mistaken for a gall. Buckton's description of the specimens sent to him is as follows:—

Psylla isitis, nov. sp.

"*Pupa.*—Colour shining yellow with the edges of the abdominal somatic rings rich brown. Vertex bristly, eyes angularly facetted, large and red. Rostrum short and stout, proceeding from between the eyes, and lying between the fore coxæ. Pronotum corrugated and tuberculose. Antenna with eight joints. the two basal joints stout and somewhat globose; the third and eighth joints the longest. Wing-cases double, but not separate. Abdomen globose, the somata edged with rich brown, and marked with stigmata. Tarsus obscurely two-jointed, ending with one claw and two bristles. The larval form is smaller than the pupal, and has less developed antennæ and feet. Size 0·05 × 0·03 of inch."

This does not give a very accurate description when compared with living specimens, and the figure given is not good.

Crawford has recently described the insect from adult specimens sent from the Pusa collection and has called it *Psyllopa punctipennis* and in his description (see page 340) says that this is probably the same as Buckton's *Psylla isitis*, but in order to avoid confusion, has given it a new name.

An examination of Buckton's type specimens leaves little doubt that the insects described by Buckton and Crawford are identical so that both names have been given.

The name "Psylla" has arisen from the name given to the insect by Buckton and has become so firmly established as a common name for the insect that it has been retained and is used as such in this Memoir.

Life-history.

The insect will breed all the year round provided that suitable food-plants are available. The time which elapses between the laying of the egg and the appearance of the adult however varies at different times in the year according to temperature

conditions. During the cold weather the period may extend to forty-six days (February and March 1913), whilst in the hot weather may be as short as fourteen days (August 1912). As would be expected therefore its attacks are most felt in the *khoontie* crop. This short period necessary for complete development, combined with the large number of eggs which each female is capable of laying explains how the crops in the field become badly attacked in a comparatively short time, especially as only a few nymphs are necessary to produce a marked effect on the plant.

The differences in the length of the period of development are shown in the following table:—

Date of oviposition.	Date of hatching.	Date of emergence of adult.	Period.
February 25th, 1912 ..	March 6th ..	March 25th ..	30 days.
March 1st	March 11th ..	March 30th ..	30 ,,
April 15th	April 24th ..	May 6th ..	22 ,,
May 10th	May 18th ..	June 1st ..	23 ,,
June 20th	June 24th ..	July 6th ..	17 ,,
July 7th	July 11th ..	July 24th ..	18 ,,
August 21st	August 25th ..	September 8th ..	19 ,,
September 8th ..	September 11th ..	September 30th ..	23 ,,
January 26th, 1913 ..	February 15th ..	March 12th ..	46 ,,
February 1st ,, ..	February 22nd ..	March 16th ..	44 ,,

The number of broods is probably from twelve to fourteen. Nine generations were traced between February and September 1912, when it was found impracticable to carry the experiment further. The generations are as follows:—

Generation.	Date of oviposition.	Date of emergence of adult.	Period.
First ..	25th-27th February 1912 ..	26th March 1912 ..	29 days.
Second ..	28th March	24th April	28 ,,
Third ..	25th April	20th May	26 ,,
Fourth ..	24th May	16th June	23 ,,
Fifth ..	21st June	8th July	20 ,,
Sixth ..	11th July	28th July	18 ,,
Seventh ..	3rd August	21st August ..	19 ,,
Eighth ..	25th (?) August ..	7th September ..	14(?) ,,
Ninth ..	10th September ..	27th September ..	18 ,,

The egg.—The egg (Plate XV, figs. 1-3) is small, spindle-shaped when seen from above, tapering to each end, one end being broader than the other. It measures ·25 m.m. in length and ·1 m.m. in thickness at about the middle. The surface of the egg-shell

is smooth. When freshly laid it is palish yellow in colour with a tinge of orange at the broader end. After a few hours it gradually darkens in colour becoming eventually quite black. This only applies to fertile eggs. Unfertilised ones become a little darker after they are laid but never become quite black and of course never hatch. The eggs are fastened to the surface on which they are laid by a curious projection of the egg-shell. About one-third of the length of the egg from the broader end the egg-shell is pulled out into a rounded protuberance which is buried in the tissues of the plant and holds the egg in position on the plant. The situation chosen by the female for oviposition is not constant, but the greatest number of eggs was observed in the groove of the rachis of the leaves. Almost any site on the plant may be chosen and eggs have been found on the stem, in the axils of the leaflets and of leaves and on the upper and lower surfaces of the leaflets. The positions are, however, always selected with a view to affording protection to the egg, for even when laid upon the stem the eggs are almost invariably placed in the grooves on the surface and when deposited on the leaves they are mostly found in the furrow of the midrib or smaller veins or by the side of raised veins.

The eggs are laid singly, the protuberance of each being thrust into the tissues of the plant separately. No definite order was observed, but the eggs are generally laid in rows at varying distances apart in a groove or furrow on the plant with their long axes pointing in the direction of the furrow, but because of the nature of their attachment to the plant never one on top of another. On the surface of the leaf or under the stipules a few are often placed side by side with their long axes parallel.

Varying numbers of eggs laid by different females have been observed, the numbers ranging from 208 to 828. The following tables give the record of the oviposition of several females:—

Two females A and B emerged on February 20th and were kept together in a cage along with several males. Between 21st and 22nd, 34 eggs were laid and the females were taken out and confined alone on separate plants. The oviposition records of

each are shown separately. Both escaped alive, A on March 15th and B on March 7th. The eggs laid by A between 11th and 15th March were not all fertile as some of them did not hatch. With B too, of the eggs laid between 3rd and 7th March, only one hatched and the rest were unfertile and failed to hatch.

OVIPOSITION RECORD OF A.

Period.	On stem.	On stem at axils of leafstalks or by the side of stipules or buds.	In groove of rachis of leaf.	At axils of leaf-lets.	On leaf-lets, upper surface.	On leaflets, under surface.	TOTAL.
10 A.M. 22 Feb. to 10 A.M. 23 Feb.	1	..	4	1	1	3	10
10 A.M. 23 ,, to 4 P.M. 24 ,,	4	5	6	..	1	6	22
4 P.M. 24 ,, to 9 A.M. 25 ,,	2	1	..	..	1	3	7
9 A.M. 25 ,, to 2 P.M. 27 ,,	7	23	34	.	..	7	71
2 P.M. 27 ,, to 11 A.M. 28 ,,	1	2	6	4	..	..	13
11 A.M. 28 ,, to 10 A.M. 29 ,,	..	9	2	..	..	5	16
10 A.M. 29 ,, to 4 P.M. 1 Mar.	..	10	13	12	7	13	55
4 P.M. 1 Mar. to 11 A.M. 2 ,,	..	..	2	2	..	3	7
11 A.M. 2 ,, to 11 A.M. 3 ,,	3	24	17	6	3	5	58
11 A.M. 3 ,, to 9 A.M. 4 ,,	..	4	3	3	1	..	11
9 A.M. 4 ,, to 10 A.M. 5 ,,	3	8	10	5	2	3	31
10 A.M. 5 ,, to 4 P.M. 7 ,,	..	24	17	11	2	6	60
4 P.M. 7 ,, to 2 P.M. 11 ,,	..	48	55	40	..	16	159
2 P.M. 11 ,, to 8 A.M. 15 ,,	2	5	9	..	..	2	18
							538

OVIPOSITION RECORD OF B.

Period.	On stem.	On stem at axils of leafstalks or by the side of stipules or buds.	In groove of rachis of leaf.	At axils of leaf-lets.	On leaflets, upper surface.	On leaflets, under surface.	TOTAL.
10 A.M. 23 Feb. to 9 A.M. 25 Feb.	2	8	16	..	1	2	29
9 A.M. 25 ,, to 3 P.M. 27 ,,	8	22	25	11	..	17	83
3 P.M. 27 ,, to 4 P.M. 1 Mar.	16	7	16	16	1	11	67
4 P.M. 1 Mar: to 11 A.M. 3 ,,	..	1	7	7	1	2	18
11 A.M. 3 ,, to 4 P.M. 7 ,,	..	2	9	..	..	..	11
							208

Female C emerged on March 11th, was provided with a male of the same date, was found coupling on March 12th at 9 A.M., and remained in copulation till 10-35 A.M. Eggs were found laid the next morning. 274 eggs were laid in all and all were fertile

and hatched. On March 24th the female was found dead, stuck to the earth in the pot. The oviposition record is as follows:—

FEMALE C.

Period. From	Period. To	On stem.	On stem at axils of leaves or by side of stipules and buds.	In groove of rachi. of leaf.	At axils of leaf-lets.	On leaflets, upper surface.	On leaflets, under surface.	TOTAL.
10-35 A.M. 12 Mar.	9 A.M. 15 Mar.	..	1	5	1	4	5	16
9 A.M. 15 ,,	8 A.M. 18 ,,	..	9	40	3	1	9	62
8 A.M. 18 ,,	3 P.M. 21 ,,	4	39	67	13	3	27	153
3 P.M. 21 ,,	23 ,,	3	11	11	9	..	9	43
								274

Female D emerged on the morning of March 30th and was provided with a male which had emerged the day before. The male escaped on April 7th and the female was given another male of this date. The second male too escaped on the 14th and was replaced by a third male. On the 16th April the insects were found coupling at 4 P.M. and ceased to couple at 4-50 P.M. The female died, apparently a natural death, on April 22nd. All the eggs were fertile and hatched. The oviposition record is as follows:—

FEMALE D.

Period. From	Period. To	On stem.	On stem at axils of leaf-stalks or by side of lateral buds or stipules.	In groove of rachis of leaf.	At axils of leaf-lets.	On leaflets, upper surface.	On leaflets, under surface.	TOTAL.
30 Mar.	10 A.M. 7 April.	5	36	63	21	7	29	161
10 A.M. 7 April.	10 A.M. 14 ,,	6	91	128	25	3	37	290
10 A.M. 14 ,,	10 A.M. 16 ,,	47	10	21	4	3	..	85
10 A.M. 16 ,,	9 A.M. 21 ,,	1	119	54	..	..	..	174
9 A.M.	....	..	..	..	..	..	..	
								710

Female E emerged on the morning of March 30th and was provided with a male of the same date. Coupling was observed at 2-45 P.M. and continued till 4-20 P.M. on the 1st April. A live

male was kept in the cage with the female as long as the latter was alive. On the 21st April she was not so active and seemed to be getting old; she had laid 828 eggs and might possibly have laid some more, but she was injured slightly and could not retain her position on the plant. She died on this date. All the eggs were fertile and hatched. The oviposition record is as follows:—

FEMALE E.

PERIOD.		On stem.	On stem at axils or leaf-stalks or by side of stipules or buds.	In groove of rachis of leaf.	At axils of leaflets.	On leaflets, upper surface.	On leaflets, under surface.	TOTAL.
From	To							
31 Mar.	10 A.M. 7 April.	4	35	46	14	..	33	132
10 A.M. 7 April.	10 A.M. 14 ,,	15	122	101	50	3	124	415
10 A.M. 14 ,,	10 A.M. 16 ,,	9	22	43	1	..	16	91
10 A.M. 16 ,,	9 A.M. 21 ,,	9	16	56	7	..	102	190
								828

Female W emerged on February 17th and was given a male of the same date. On the next day the male was not to be found. On the 22nd February a fresh male was supplied. On the 1st March copulation was noticed at 3-30 P.M. and no eggs had been laid till this date. On the 11th March the male was isolated and it lived until April 1st. The female died on March 27th. The eggs laid between 25th and 27th March did not hatch and were apparently unfertile. The oviposition record is as follows:—

FEMALE W.

PERIOD.		On stem.	On stem at axils of leaf-stalks or by the side of stipules and lateral buds.	In groove of rachis of leaf.	At axils of leaflets.	On leaflets, upper surface.	On leaflets, under surface.	TOTAL.
From.	To.							
1 Mar. when coupled	3 P.M. 11 Mar.	17	44	27	35	2	19	144
3 P.M. 11 Mar.	8 A.M. 15 ,,	..	34	18	22	3	10	87
8 A.M. 15 ,,	8 A.M. 18 ,,	..	26	10	9	..	1	46
8 A.M. 18 ,,	9 A.M. 25 ,,	3	12	10	3	..	..	28
9 A.M. 25 ,,	27 ,,	6	2	..	1	..	..	9
								314

In the fields it has often been noticed that one plant may be literally covered with eggs while the plants surrounding it may have hardly any eggs on them. It is curious that the female or females will remain depositing hundreds of eggs on the same plant while only a short jump is necessary to reach other plants. The following record shows the number of eggs found on two such plants:—

No.	On stem including those at axils of leaf-stalks.	In groove of rachis of leaf.	At axils leaflets.	On upper surfaces of leaflets.	On lower surfaces of leaflets.	TOTAL.
1	93	137	58	192	199	679
2	70	168	49	102	201	590

In the Insectary, too, the same habit has been observed. In one case a female had access, between the 27th February and the 1st March, to two plants growing in the same pot; she laid 67 eggs on one plant while there was not a single egg deposited on the other. In two other similar cases the females confined with the plants for 24 hours deposited all the eggs on one plant and neglected the second plant altogether. This emphasises the sluggish nature of the adult insect which probably does not leave a plant unless compelled to do so. The period from the laying of the egg to hatching varies, according to season, from five to twenty days, the latter extended period being during January and February. From March to September the period varies from five to twelve days and it is during this period that the insect is most active.

Hatching of the egg.—The egg-shell bursts at the narrower end and the larva which is of a pale yellow colour wriggles its way out. When it emerges from the egg its legs are closely applied to the body and it is held upright in the air by the hinder part being still retained inside the egg-shell. After a while it moves its limbs and bending forward crawls out of the egg-shell on to the leaf of the plant. The egg-shell then closes up again and retains its normal shape, the fissure through which the larva emerged being unobservable even under a low power lens, so that it is difficult to distinguish between hatched and unhatched eggs.

The Larva or Nymph.—The freshly emerged larva (Plate XV, fig. 4) is at first of a uniform pale yellow colour, the eyes only being red. The colour darkens gradually until in the course of a day it is of a general brownish black, the appendages being darker than the body. The divisions of the body are marked by light yellow coloured lines and there is a light coloured median line from the head to the abdomen. The nymph passes through five moults before attaining the winged adult stage.

The time taken for each individual stage in the development of the nymph has only been observed at one period, during March and April 1912, and the results are given in the following table :—

No.	Date of hatching of egg.	Date of 1st moult.	Date of 2nd moult.	Date of 3rd moult.	Date of 4th moult.	Date of 5th moult.
1	16th March 1912	23rd March	25th March	28th March	2nd April	8th April
2	31st ,, ,,	4th April	6th April	8th April	10th ,,	14th ,,
3	31st ,, ,,	4th ,,	7th ,,	10th ,,	12th ,,	15th ,,
4	31st ,, ,,	4th ,,	6th ,,	8th ,,	10th ,,	15th ,,
5	31st ,, ,,	4th ,,	6th ,,	8th ,,	10th ,,	14th ,,

The larva in the first stage is very small, the measurements of a larva three days old being :—

Length from head to tip of abdomen	·3 m.m.
Breadth	·15 ,,
Length of antenna	·07 ,,

Very careful examination is necessary to observe it on the plant. The young larvæ usually crawl up the plant until they reach the young leaves at the growing point, and crawling in among the leaves insert their probosces and commence to suck.

After the first moult signs of the presence of wing pads are observable (Plate XV, fig. 5) and the insect has increased in size, the dimensions of a nymph in this stage being:—

From head to tip of abdomen	·5 m.m.
Breadth across the eyes	·25 ,,
,, ,, prothorax	·28 ,,
,, ,, middle of abdomen	·22 ,,
Length of antenna	·09 ,,
Length of wing pads (anterior)	·08 ,,
,, ,, ,, (posterior)..	·05 ,,

A more marked differentiation of the parts of the body is seen, and the colour scheme has changed somewhat, the head and thorax

being of a greyish tinge, and the abdomen pale yellow. The appendages still remain of a dark brownish black, and the eyes red.

In the third stage (Plate XV, fig. 6) little difference is noticeable except increase in size and lengthening of the wing pads.

Length from head to tip of abdomen	·63 m.m.
Breadth across the eyes	·25 ,,
,, ,, prothorax	·26 ,,
,, ,, middle of abdomen	·3 ,,
Length of antenna	·16 ,,
,, ,, wing pads (anterior)	·1 ,,
,, ,, ,, ,, (posterior)	·08 ,,

In the fourth stage (Plate XV, fig. 7) the wing pads are very distinctly enlarged and the colouration of the nymph is generally of a lighter yellow shade, the appendages alone being darker in colour. The abdomen is long in proportion to the rest of the body.

Length from the head to the tip of abdomen ..	1·0 m.m.
Breadth across the eyes	·4 ,,
,, ,, thorax	·4 ,,
,, ,, abdomen	·44 ,,
Length of wing pads (anterior)	·22 ,,
,, ,, ,, (posterior)	·12 ,,
,, ,, antenna	·3 ,,

In the fifth and last nymphal stage (Plate XV, fig. 8) very marked differences are noticeable, the parts of the body and appendages being much more clearly differentiated. The general colour scheme has now become of a dark brownish black, the legs and wing pads and lobes being of a dusky yellow colour with darker shades round the edges. The distal portion of the antenna is black and the remaining part yellow. The entire surface of the body is speckled with grey or whitish markings. The antennæ now show clearly eight distinct joints and the wing lobes have become much longer, the posterior ones being almost entirely covered by the anterior ones.

Length from the head to the tip of the abdomen ..	1·5 m.m.
Breadth across the eyes	·5 ,,
,, ,, the abdomen	·75 ,,
,, between the margins of the anterior wing lobes	1·0 ,,
Length of anterior wing lobes	·5 ,,
Length of the antenna	·5 ,,

The larvæ and nymphs in all stages exude globules of fluid which have a greyish white appearance. The globules are extruded from the anus and consist of liquid excreta covered over with a waxy secretion.* If a globule is placed on a glass slide and pricked with a needle the globule bursts discharging its fluid contents, the waxy covering remaining on the slide.

The nymph moulting for the last time gives rise to the winged adult (Plate XV, fig. 9). The skin of the nymph bursts along the back in the middle line. The insect gradually liberates itself from the skin and moves a little forward along the leaf and remains quietly sitting. The colour is a general pale yellow, except the eyes which are red brown. The wings, which are of course still unexpanded, are about the size of the wing pads in the last nymphal stage. In the insect observed, the wings after a lapse of 45 minutes became fully expanded but no change of colour was noticeable, this not taking place until nearly two hours after emergence.

The young nymphs after hatching from the egg crawl about on the plant and almost invariably come to the top of the stem where they can obtain a good supply of sap. They creep into or between the unfolded tender leaflets and sit hiding there and sucking the sap. If no secure place is to be found among the tender leaflets the nymphs crowd under the stipules. If lateral shoots with tender leaves or newly developing lateral buds are found, many lodge themselves there. The previously mentioned liquid excrement appears in all sorts of shapes, such as pearly globules or long tubules and often quite fantastic forms. The excrement falls on to the leaves and branches, and in moist weather a black mould grows on it giving the plants a blackened, burnt-up appearance. As long as there is food available the nymphs do not desert the plant on which they hatch. It has been observed in several

* In *Psylla mali*, an insect which is very troublesome on apple trees in England, two glands have been found one on either side of the anus and it is possible that the waxy secretion is produced by these glands and covers the excrement as it is extruded. This insect produces the same kind of greyish white globules.—A. J. G.

cases that out of two plants growing in the same pot, one on which no eggs were laid remained free and grew healthily while the other harboured and fed numerous nymphs. The nymphs usually live hidden under the curled leaves inside the crumpled head. When, however, they are full grown and about to become winged they leave their hiding places and come to the stem or open leaves so that the emergence of the adults may not be impeded. For this reason nymphs in the advanced stages frequently sit exposed on the stem, at axils of leaf-stalks or on leaves.

The formation of Colonies.—Colonies of nymphs, consisting sometimes of several hundred individuals, are occasionally formed on the stem below the crumpled head. Nymphs in all stages of growth are found congregated together and are entirely exposed exactly like an aphis colony. Such colonies were not noticed earlier than September. It was then observed that when a large number of nymphs hatched on a head in the leaves of which there was not room for all, or on a head which had practically withered, the nymphs settled on the stem in colonies. Sometimes colonies were formed a great distance below the head of the plant. This gregarious habit renders the nymphs liable to a special danger, *viz.*, the predaceous Syrphus fly, *Pelecocera* sp. described later. In the several plots of indigo kept under observation the Syrphus fly appeared only after the nymphs had begun to form such colonies in exposed places.

The adult.—The adult has recently been described by D. L. Crawford (Indian Museum Records, Vol. VIII, p. 431). His description is as follows :—

"*Psyllopa punctipennis*, n. sp.

Length of body 1·7 m.m.; length of fore-wing 2·3 m.m.; greatest width 1·0 m.m.; width of vertex between eyes ·33. m.m.; with eyes ·53 m.m. General colour light brown; dorsulum and scutum with several dark brown longitudinal stripes, antennæ black at tips of segments III to X; fore-wings with numerous brown or black dots and spots both on veins and membrane.

Head a little narrower than thorax, not much deflexed; vertex longer than half its width, with a slight foveal impression discally; facial cones about two-thirds as long as vertex rather strongly divergent, narrowly rounded at tip; eyes larger; antennæ less than twice as long as width of head, slender.

Thorax not strongly arched; pronotum rather long; pleurites broad. Legs typical. Fore-wings hyaline, rounded at apex, relatively rather small, about two and a third times as long as broad; cubital petiole a little shorter than discoidal subcosta.

Male.—Genital segment rather large; anal valve broad at base, truncate at apex; claspers rather blunt at tip.

Female.—Genital segment thick, about half as long as rest of abdomen, valves subequal, rather thickly pubescent.

Described from four males and four females from Pusa, Bengal, on indigo. This is probably the adult of Buckton's *Psylla isitis* which he described from the nymph only. In order to avoid confusion, however, in case they should not be identical, I have given it another name. The fore-wing of this species bears a close resemblance to *Aphalara multipunctata*, Kuwayama (Japanese)."

The males are easily distinguishable from the females by the marked upturning of the tip of the abdomen (Plate XV, fig. 10) enclosing the accessory sexual organs, the tip of the abdomen of the female being pointed. Coupling has been observed to take place in two ways, either end to end, the axes of the bodies of the two insects being in the same straight line, their heads being turned in opposite directions or, with the axes of their bodies forming the acute angle, the heads of the insects facing in the same direction, the latter being the usual mode. The exact length of the period occupied in copulation was not determined, but couples were observed together for up to one hour and 50 minutes. After copulation the female, as described previously, begins to lay eggs fairly soon.

In the Insectary with a good supply of food the adults, both male and female, lived for up to 39 days. Their usual mode of

locomotion is a sort of flitting from plant to plant. When one disturbs them while they sit on a stem, leaf-stalk or leaflet, they try to evade pursuit by moving on to the opposite side. If the attempt is continued they may walk a little but usually flit away. Although active when provoked they seem to be naturally sluggish. This has been referred to while discussing oviposition. As a rule they do not leave the plant on which they become winged and a number of adults will sometimes be found sitting and mating on plants which still harbour a large number of nymphs. The adults are scarcely ever found sitting exposed to the hot sun. Also when it rains they sit on the under surfaces of leaflets or on leaf-stalks and stem under cover of leaves.

The adults are not attracted by light. On a dark night on the 16th August an acetylene gas light-trap was set up in an affected plot of indigo in which it was ascertained by examination the previous evening and also the next morning that there were numerous adults both male and female. To the trap were attracted several hundreds of bugs, beetles and moths but only five "Psylla" adults, one female and four males.

THE EFFECT ON THE PLANT.

The damage to the indigo plants is very marked (Plate XVI, figs. 1 & 2). The leaves around the growing point of the attacked plants become curled and twisted up into a knot at the top of the stem, the twisting and curling becoming more and more pronounced as the attack proceeds until finally in the case of Java indigo, the head of the plant forms a hard knot of blackened curled leaves involving the death of the growing point. The effect on the Sumatrana plants too is much the same, the same kind of curling being produced, but on account of the long internodes there is not the same compact knot. The plant usually then tries to compensate for this by throwing out fresh branches from the axillary buds and giving the plant a bushy appearance. These fresh branches in their turn may become attacked by the insect

PLATE XVI.

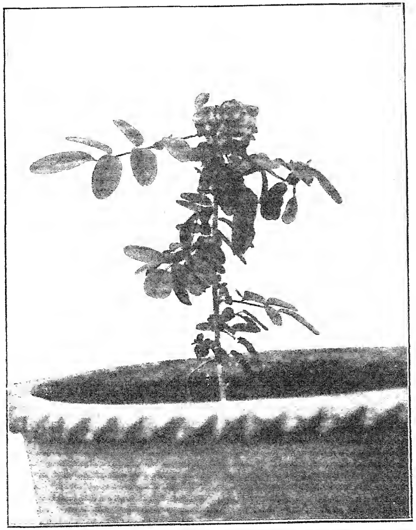


Fig. 1. An affected plant showing the tightly curled knot of leaves around the growing point.

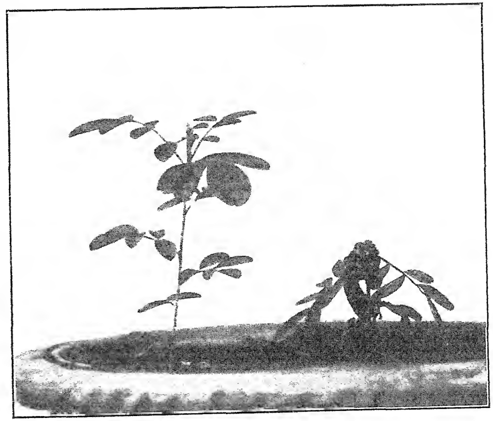


Fig. 2. Unaffected and affected plants of the same age.

and soon present the appearance of the original plant and if the attack be continued, especially if the plant is young, the plant will be killed outright.

The different species of *Psyllidæ* affect their host plants in different ways. Some merely weaken the plant by sucking its juices but do not cause any malformation. Others, in addition to, or as a result of, sucking their food from the plant, cause gall-like growths to develop, in which they pass their life-history. "Psylla" seems to be intermediate between these two forms, for although no gall is formed the leaves become distorted in shape and growth. It is not known exactly how this alteration in the form of the plant is brought about, but it is probable that the insect in the process of sucking injects some kind of secretion from the salivary or other glands which causes the cells of the plant at the point of puncture to grow unequally, thus producing the malformation. An examination of young leaves just beginning to curl shows that the folded-up leaf begins to curl before the halves open out, and that young nymphs are generally to be found in between the folded halves. This may possibly be explained by the fact that the nymphs secure between the folded halves suck for some time from one-half only, this causing a retarding or acceleration of the growth of that half, while the other half is growing naturally resulting in the curling of the leaf in one direction or the other. In the case of indigo "Psylla" it is only the nymphs which cause the leaves to curl; the adults producing no malformation of the plant as the following experiment shows :—

Four freshly emerged adults were placed upon a healthy plant of Java indigo on 22nd February 1912, and remained on the plant until 20th of March when the plant becoming attacked by red spiders (*Tetranychus*), the insects were removed to a fresh one, on which they lived until between the 26th and the 29th March when they died. On neither plants was there any curling noticeable. The effect of the nymphs is very different. On the 17th February 1912, two plants in a pot were infested with

three nymphs each and on 19th and 20th, respectively, one nymph from each became adult. Yet on the 23rd the leaves of the plants were distinctly curled. It has already been mentioned that the young nymphs after hatching from the eggs invariably come to the tender unopened leaves and suck from them. It was observed in a long series of plants on which adults were made to lay eggs in the Insectary that the newly hatched young nymphs were able to cause distinct curling of the top leaves within two days and to produce the typical crumpled head within a week. It was also found that a single nymph was sufficient to cause crumpling of the leaves.

If the attack on the plant ceases after a time, and has not been severe enough to kill the growing point, the plant will grow through the twisted head and produce normal leaves again. The malformed leaves do not recover, however, though they may grow and open out to some extent. This is shown in fig. 2, Plate XVII, the history of the plant being as follows. Eggs were laid on the plant on 22nd and 23rd February 1912, and hatched on 5th March. Crumpling of the leaves was noticeable by the 14th and the nymphs became adult by the 25th. The adults were not allowed to lay eggs on the plant and it was kept under ordinary conditions with the result shown in the photograph, where it is seen that the leaves around the growing point are quite normal, whilst those lower down about the position where the growing point was at the time of attack, are crumpled and twisted. The effect has also been observed in the field where the crop has recovered under favourable circumstances from a previous attack. Plates XVIII & XIX are a series of photographs of the same plant to show the progress of the disease. A female was confined on the plant on 16th April and eggs were laid on it up to 21st. Hatching commenced on the 23rd and curling was evident by the 27th. Adults appeared on the 7th May and were allowed to lay eggs on the plant. Adults again appeared on 16th May and by June 6th all the nymphs had become adult and left the plant. At this time the growing point of the plant was practically dead, and several side shoots had been given off and had been

PLATE XVII.

Fig. 1. Affected and unaffected plants of the same age. The affected plant has been killed out and the unaffected one grown naturally

Fig. 2. A Plant recovering from the attack. The curled leaves are seen on the stem in the position where the growing point was when the attack occurred.

PLATE XVIII.

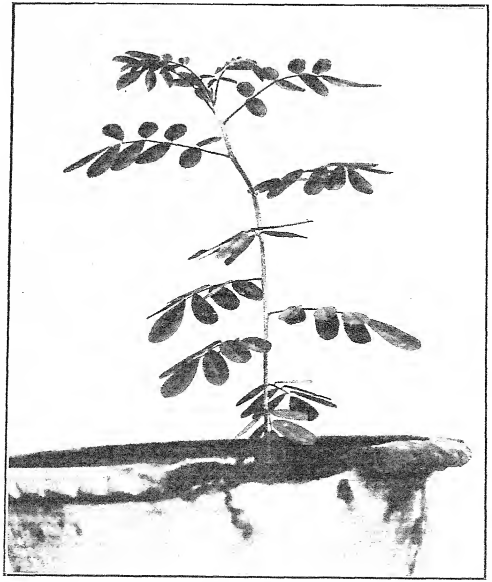


Fig. 1. To show the appearance of the plant at the time of inoculation (April 23rd 1912).

Fig. 2. The plant 13 days after inoculation (May 5th 1912).

PLATE XIX.

Fig. 1. The plant 25 days after inoculation (May 17th 1912).

Fig. 2. The appearance of the plant on 29th June 1912, 68 days after inoculation. The growing point is practically dead, side branches have been given off and these in turn are affected.

attacked. Fig. 2, Plate XIX, gives the final appearance of the plant on June 29th.

Food-Plants.

As the growers know to their cost, "Psylla" feeds on both the varieties of indigo at present cultivated in Behar, *viz.*, Sumatrana (*Indigofera sumatrana*) and Java (*Indigofera arrecta*).

Mr. Bergtheil, Director of the Indigo Research Station (now closed) at Sirsiah, was kind enough to supply seeds of the following species of indigo with the remarks noted against each species :—

I. paucifolia, from Forest Office, Dehra Dun, possibly a variety of *Sumatrana*.

I. anil, from Georgetown, British Guiana.

I. oligosperma.

I. tinctoria, sent and so-called by U. S. A. Bureau of Plant Industry ; certainly not rightly named since it yields no indigo.

He also supplied seeds of *Polygonum tinctorium*, a Chinese indigo plant (seeds from plant grown at Sirsiah) and said that all except *I. tinctoria* were indigo-yielding. The seeds were sown in the Insectary compound, but *Polygonum tinctorium* did not grow. "Psylla" was found to feed and breed on *I. pauciflolia*, *I. anil* and *I. oligosperma* and curl their leaves in the same way as Sumatrana and Java-Natal. "Psylla" would not feed on the so-called *I. tinctoria.*

Thus it is definitely known that the insect feeds and breeds on :—

I. arrecta, "East African" or "Natal" or "Java" indigo. It is an introduced plant now cultivated in Behar.

I. sumatrana, Bengal indigo. This is also cultivated in Behar. According to Prain, it is occasionally spontaneous in Tamarisk jungles and on river banks. Under this Prain includes *I. tinctoria* mentioned by Roxburgh (*Flora Indica*) who describes it as "native place uncertain, for though now common in a wild state over most parts of India yet is in general not remote from places where it is or has been cultivated," and also part of *I. tinc-*

toria mentioned by Hooker (*Flora of British India*) as "the universally cultivated indigo," but he states further that it is doubtful whether it is truly wild. This too is probably an originally introduced plant.

I. paucifolia. Mr. Bergtheil says this is possibly a variety of *Sumatrana*, but Hooker puts it down as a distinct species giving its habitat as "Plains from Scinde and the Upper Ganges to Ceylon."

I. anil, West Indian indigo. It is said to be sometimes grown.

I. oligosperma is not known to grow in Behar.

Prain mentions six species of *Indigofera* occurring as weeds in Behar. (*I. echinata*, Western Behar; *I. linifolia; I. cordifolia; I. glandulosa*, Western Behar; *I. endecaphylla*, Western Behar; *I. tinctoria*). Of these the species commonly found is *I. linifolia*, a small creeping weed which grows in lawns, pastures and waste lands. No "Psylla" was found on it and all attempts to rear nymphs and adults on it failed. The insects therefore probably cannot breed on it. In the Insectary eggs were laid on this plant by females confined with it, but the nymphs which hatched from these eggs did not feed, and deserted it. None of the remaining five species was tried as they were not available. It is, therefore, not known whether "Psylla" will feed on them. According to Prain, another species, occurring wild in Behar, is *I. articulata*, Surat indigo, which too is an introduced plant and used to be cultivated formerly until displaced by Sumatrana. It is not known whether "Psylla" feeds on this species. He also says that sometimes Guatimala indigo, *I. guatimalensis*, is cultivated. It is not known whether "Psylla" feeds on this species either. Stray plants of both the species of indigo cultivated at present, *viz.*, Java and Sumatrana, are found all over Behar. It is certain that such volunteer plants occur of those species of indigo which had once been cultivated but have now been displaced or which are cultivated only occasionally.

The plants on which "Psylla" feeds ordinarily in Behar, that is the varieties of indigo which are cultivated, are introduced plants,

but it has always been considered that the insect itself is indigenous. It is probable therefore that the insect has other food-plants which occur naturally in Behar and upon which it can live. Attempts were made to discover these plants but without success.

The discovery of the wild food-plants will not probably be a material help in checking "Psylla" under the present conditions as the volunteer food-plants are there and also indigo is in the fields from year's end to year's end. The insect, therefore, is in no want of food throughout the year.

The plants, which have been definitely proved to support "Psylla" and enable it to multiply, are indigo-yielding. An attempt was made to find out whether the insect would feed and breed on plants other than *Indigoferas*, but which contained the substance indican. The following two species were tried but the attempts were unsuccessful:—

Tephrosia purpurea, a perennial herb, common in waste places and by way-sides. This is known in the vernacular as "ban-nil," *i.e.*, "wild indigo."

Tephrosia sp., a variety growing at Sirsiah from whence seeds were obtained.

When Sumatrana was the only indigo grown it was in the land from March to October. Therefore the insects had to depend on other food-plants from November to March. It is uncertain whether it then resorted to its presumed wild food-plants and bred on them, or whether the winged adults lived on other plants and waited through the winter to lay eggs on indigo when it would be again grown in March. If there are wild food-plants present, the former would be the course adopted and there would be no necessity for the adults to wait, especially when, as it has been definitely observed, the cold of winter in Behar does not inhibit breeding. A long series of plants was tried to test if adults would feed and live on plants other than *Indigoferas*. The plants were grown in pots and adults, both males and females together were confined with them as much under natural conditions as possible. The

"Psylla" adults died after two to four days, while under the same condition they live for more than forty days on indigo. Also no eggs were observed to be laid. The plants tried were the following :—

Wheat; Barley; Maize; Pea; Linseed; Cotton; Castor; Tobacco; Sweet potato; Brinjal; Chillie; *Physalis minima; Heliotropium indicum;* Cauliflower; Radish; Aniseed; Jute; a Weed (*Corchorus* sp.); *Akh* (*Calotropis gigantea*); Turmeric; Artichoke; Guma (*Leucus* sp.); *Justicia* sp.; Elephant's Foot; Prahlad (*Ocimum canum*); *Chhatwan* (*Alstonia collaris*); Mango; Papaya; Arum; *Phyllanthus niruri;* Lily; *Dodonea viscosa; Commelyna bengalensis; Mutha* (*Cyperus rotundus*); *Kodo* (*Paspalum scrobiculatum*); *Sama* (*Panicum frumentaceum*); *Marua* (*Eleusine Coracana*); *Juar* (*Andropogon Sorghum*); *Dub* (*Cynodon dactylon*); *Mung* (*Phaseolus Mungo*); *Urid* (*Phaseolus radiatus*); *Arhar* (*Cajanus indicus*); *Chakour* (*Cassia occidentalis, C. sophera & C. tora*); *Amaltas* (*Cassia Fistula*); *Sissoo* (*Dalbergia Sissoo*); *Lajwavati* (*Mimosa pudica*); *Kouni* (*Setaria italica*); *Kanghani* (*Abutilon indicum*); *Simul* (*Bombax malabaricum*); *Chota Dudhi* (*Euphorbia thymifolia*); *Dudhi* (*Euphorbia pilulifera*); *Ghurmi* (*Cephalandra indica*); *Gular* (*Ficus glomerata*); *Pakur* (*Ficus infectoria*); *Pipal* (*Ficus religiosa*); *Rai* (*Brassica juncea*); *Sarson* (*Brassica campestris*); *Bariar* (*Sida* sp.); *Suthni* (*Dioscorea fasciculata*).

This list includes, amongst other plants, almost all the weeds which commonly grow in or near indigo fields.

Effect of Manuring on Affected Plants.

In order to determine if plants well-treated with manure could resist the curling of the top caused by the feeding of "Psylla" nymphs, a few series of experiments were carried out with superphosphate and oil-cake. The plants were grown in pots.

There was no difference in the effect of the attack by the insect on manured and unmanured plants. Both were curled to the same extent and in the same way. As soon as curling of the top occurs and checks the growth of a manured or any vigorously growing plant, it begins to give out lateral branches and become bushy. Thus if there had been only one attack of "Psylla", that is, if the insect had fed on the plants for only one generation and then left them, probably the attack would have been a blessing in disguise; as it would have made the plants grow bushy and produce more leaves. But actually all fresh shoots are attacked as soon as they appear and the growth of the branches as well is stopped.

How Infection Takes Place.

Infection of new areas is probably effected by females flying over to them and in these cases the insects are probably helped by the wind. In this way infection is spread from one place to another as the following instance illustrates. A plot of Java indigo was sown on the Farm at Pusa in October 1911, the nearest indigo cultivation being at least two miles away, and no indigo had been grown on the Farm for years. On 28th February 1912, a number of plants showed signs of attack and nymphs were found on them. In some cases, however, the insect does not seem to spread very rapidly, for a small plot of Java indigo sown in the Insectary compound on 29th November 1911, remained free from attack until the end of June, although the formerly mentioned plot was attacked in February, though in this case the plants were grown in among Kusum (*Carthamus tinctorius*) plants, these latter plants being removed on the 21st April 1912. The facilities for infection were very great, however, for breeding experiments were being carried out in the Insectary from February onwards and infected plants in pots were often standing in the verandah at a distance of not more than ten yards from the plot, and it would have been a very simple matter for winged insects to fly from these plants into the plot.

It has also been observed that infection is either prevented or retarded when the adults meet with some sort of obstruction. Thus Java-Natal indigo was grown in a big wire-gauze cage attached to the Insectary. The wire-gauze had about 10-12 meshes to the linear inch which would allow easy passage to "Psylla" adults. The indigo was growing from November 1911 to January 1913, but no insects appeared in this cage although it was breeding profusely at a distance of about 5 yards. It was observed on other occasions that when indigo was sown together with other crops such as wheat, linseed, mustard, the young plants showed little or no sign of attack when the covering crop was removed, whilst other indigo grown in the ordinary way and in its immediate vicinity was badly affected.

The spread of infection in a plot of indigo seems almost always to be effected by the adults, though it is possible that the nymphs may leave one plant and crawl over the ground to a fresh one. To test the capacities of the nymphs for walking over the ground, the following tests were made. Twenty-five nymphs of different stages were placed at 10 A.M. on earth which had been smoothed in a pot in which a plant of indigo was growing. Five more shoots of indigo were then stuck into the earth at intervals of about two inches. The nymphs immediately crawled away in different directions at the rate of about an inch a minute. The first one crawled on to a shoot within a minute and-a-half, and at the end of ten minutes seven nymphs were on the shoots. At 4 P.M. it was found that sixteen nymphs had crawled on to the plants, three were found dead on the rim of the pot, and the remainder had disappeared probably having crawled right away from the pot.

A large number of nymphs were placed on the ground in a field which had been ploughed and afterwards smoothed down by rain. They were found to be able to walk over a distance of about five to six feet or more. They did not make much progress because they wandered about, got upon any plant or stick they came across and also fell an easy prey to ants and other predaceous enemies. When they could not get to the proper food-plants,

they died within a day for want of nourishment. It has also been found by placing the nymphs in ploughed up lands with a loose surface that they travelled extremely slowly, and in fact could hardly make any progress at all. The nymphs and adults also do not seem to be able to withstand the absence of food for long. Seven crumpled heads with many nymphs in all stages, and five adults were placed in a glass dish with a wire gauze cover at 7 A.M. At 7 A.M. the next morning the shoots were found to have withered a great deal and that two of the adults were dead and also that many of the nymphs had left the shoots and were walking about in the dish. By 4-45 P.M. the shoots had withered considerably and only one adult was living, the nymphs had all left the shoots and many of them were dead. At 10 A.M. on the third day it was found that all the nymphs and adults were dead. This fact is of interest in connection with the severe attack from which the *khoontie* crop usually suffers, for it would seem that the cutting of the crop at that time should effectually check the insect and when the plants are cut, little beyond the hard stems of the plants would remain in the field and the nymphs at any rate would be killed off.

At the time of harvesting, the operation of cutting the plants, placing them on the ground in bundles and then loading these bundles on to carts, is not at all sufficient to jerk the nymphs from the plants. Some do fall off on account of the disturbance caused, but their number is very small as has been determined by actual observation. These fallen nymphs mostly crawl on to the cut stumps and live there until new buds grow. The insects develop undisturbed on the occasional plants left standing here and there and the adults soon infect the *khoontie* plants around. Sometimes a cut plant is left lying on the ground and as it withers the nymphs crawl on the stumps which afford them nourishment for about three days or so by which time new buds sprout. Apart from these nymphs the number of which is small, the adults are the principal source of infection of the *khoontie* crop. In a newly harvested field adults

are found plentifully. They congregate mostly on the uncut plants left standing here and there. Eggs are laid on such plants and also on the stumps. The cracked epidermis of the latter affords convenient places for oviposition and when the nymphs hatch after 5 or 6 days they find the newly sprouting buds to feed upon. Also all the plants in one district are not cut simultaneously so that the winged adults can fly from locality to locality and renew the attack.

The question also arises whether the nymphs or adults are carried away to any extent with the plant when it is taken to the vats. On observation it was found that the adults are not dislodged if the plants are merely shaken, as by the wind, but that if the plants are struck with a stick the sudden jerk causes them to leave the plant. The nymphs, however, are more difficult to dislodge and neither shaking, striking the plant with a stick, nor even on the ground has any effect at first, though such disturbance causes the nymphs to leave their lurking places and wander about when the effect of a sharp jerk is sufficient to dislodge them.

The infection of the *khoontie* or young crop quickly takes place if it be by the side of old infected indigo. By the side of an experimental plot of Java-Natal indigo with plants about 3 to 4 feet high a plot was sown with *Indigofera paucifolia.* "Psylla" was breeding unchecked in the Java-Natal plants. The adults bred on this old indigo showed a decided partiality towards the young *paucifolia* plants, to which they were attracted in large numbers, the young plants affording a more plentiful supply of sap.

THE EFFECT OF DEW.

In Behar the dews are very heavy from September onwards, and in the early morning the indigo plants in the field are completely covered. The insects are, however, protected by the numerous hairs on their bodies and the moisture has no effect upon them although they may be completely covered. A series of nymphs were completely covered over with dew, but the only result was that they remained quiet until the dew evaporated and then moved away.

Dew however seems to hinder egg laying and thus probably contributes towards the lessening of the number of insects distinctly noticeable in September and October. Covered with dew the adults were found to be quite lethargic and would hardly move even when touched. They became active again when the dew evaporated. Egg laying takes place mostly in the evening, at night and in early morning. But all this time the adults remain covered with dew and therefore egg laying is hardly possible.

"Psylla" and Ants.

The following six kinds of ants have been observed to attend "Psylla":—

Camponotus compressus, the common big black ant, has been observed to attend both nymphs and adults. The adult insect does not jump away even when approached and caressed by this ant. This fact is taken advantage of by the black spider which mimicks this ant and which can thus approach adults unsuspected. This spider (see *enemies*) catches and eats adults.

Tapinoma melanocephalum, a black headed small brown ant, which when pressed between fingers gives out an aromatic smell. It attends upon the nymphs.

Monomorium indicum, the common small brown house ant, has been observed to attend the nymphs. There is a small spider which mimicks this ant. It could not be ascertained whether it preys upon the insect nor could it be fed with "Psylla" in confinement.

Œcophyla smaragdina, the common red tree ant, attends the nymphs.

Camponotus sericeus has been observed attending the nymphs in company with *Œcophyla smaragdina*.

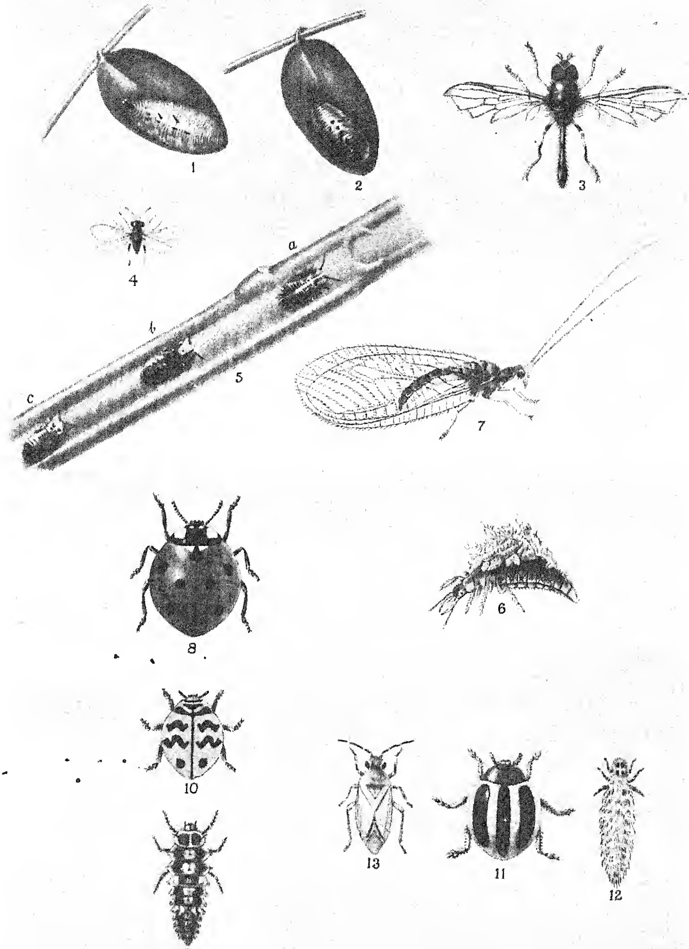
Monomorium gracillimum, a common small brown ant with a dark abdomen has been observed attending the nymphs.

The ants are attracted by the liquid excrement which they lick up by applying their mouth parts to the liquid drop as it

EXPLANATION OF PLATE XX.

1. Larva of Syrphus fly (*Pelecocera* sp.) X 3.
2. Pupa ,, ,, ,, X 3.
3. Imago ,, ,, ,, X 3.
4. Chalcid parasite X 7.
5. Nymphs of "Psylla" on a shoot.
   (*a*) A full-grown nymph. X 7.
   (*b*) A parasitised nymph. X 7.
   (*c*) A parasitised nymph from which the parasite has emerged showing the hole caused by its exit. X 7.
6. Larva of Chrysopa. X 3.
7. Imago of ,, X 3.
8. Adult of *Coccinella septempunctata* X 3.
9. Larva of *Chilomenes sexmaculata* X 3.
10. Adult of ,, ,, X 3.
11. Larva of *Brumus suturalis* X 7.
12. Adult of ,, ,, X 7.
13. ,, of *Campylomma livida* X 7.

PLATE XX.



ENEMIES OF INDIGO PSYLLA.

in a colony of a hundred, and nineteen in a colony of fifty were killed by the parasite, while one maggot of the Syrphus fly (*Pelecocera* sp.) is alone capable of destroying several such colonies in a day.

The Predators.—These destroy nymphs and adults, either eating them or sucking them dry. Among them are included three Ladybird Beetles, a Mantid, a Chrysopa, a Syrphid fly, a Capsid bug, and several spiders. These are known definitely to prey upon the insect and possibly other insects and animals also do so.

The Ladybird Beetles are the seven-spotted *Coccinella septempunctata* (Pl. XX, fig. 8), the six-spotted *Chilomenes sexmaculata* (Pl. XX, fig. 10) and the striped Ladybird Beetle *Brumus suturalis* (Pl. XX, fig. 11). These beetles as well as their larvæ feed principally upon the nymphs and also upon the adults when they can be caught. Figure 9 in Plate XX shows the larva of the six-spotted Ladybird Beetle. The larva of the seven-spotted Ladybird Beetle is similar in appearance but having yellow spots in addition. Figure 12 in Plate XX shows the larva of *Brumus suturalis*. The white tufts on its back give it a characteristic appearance.

The Mantid which has been observed to eat "Psylla" nymphs and adults but mostly adults, is the green one, *Hierodula westwoodi*, commonly found among green vegetation.

The Chrysopa, whose larva has been observed (Pl. XX, figs. 6 & 7) to feed mostly upon the nymphs is the common green one, *Chrysopa alcestis*. The larva has the habit of piling upon its back the empty skins of the nymphs it destroys.

The Syrphid fly (Pl. XX, figs. 1—3) is the most important of all the enemies as it is capable of destroying a large number of the nymphs in a short time. The maggot feeds upon the nymphs only, and during the latter part of its larval history will destroy about 300 to 400 of them in a day. A maggot is shown resting on a leaf in fig. 1, Pl. XX. When it walks or feeds the anterior part of the body is extended and is then tapering in appearance. At the dorsal area of the hind end there is a pair of brown tubes

joined together and giving the appearance of a tail. These are the spiracular openings. The maggot strikes its head apparently blindly in all directions and on the backs of the nymphs, but some nymphs are passed over. It does not pierce the prey from the back, but moves its head round to the ventral surface and then pierces the thorax. The contents of the body are then eaten and the empty skin discarded. The maggot is a voracious eater and feeds almost continuously with but short periods of rest for moulting. It takes about one to four minutes to finish eating a nymph, the time varying according to the size of the prey. Dead parasitised nymphs are always passed over and never destroyed. Membracid nymphs sitting near or in the midst of "Psylla" colonies were not observed to be eaten, but the maggot preys readily on other younger and smaller *Syrphus* maggots which it may come across. When it is full grown it fixes itself by the tail end on either of the surfaces of a leaf or on the stem and pupates there. The anterior end of the pupating maggot is much contracted so that this end of the pupa is rounded (Pl. XX, fig. 2). The fly (Pl. XX, fig. 3) emerges after about seven days. Ordinarily when found in indigo fields it may be mistaken for a small *Eumenes* wasp. It does not exhibit the hovering flight characteristic of *Syrphus œgyptius* and flies more like a *Eumenes* wasp with the abdomen raised than like a fly. Eggs are deposited singly near "Psylla" colonies. Each egg is cylindrical and slightly bent on one side; one end is slightly thicker and rounded, the other end being tapering and blunt. It measures ·7 m.m. long, ·35 m.m. broad and is white in colour. The surface is reticulated, there being fine zig-zag lines noticeable on it under a high power lens. The thicker end is gummed to the substratum and the egg lies on its concave side.

The maggot is found to be parasitised by a small *Chalcid*. It pupates with the parasitic grubs inside its body, the adult parasite emerging by a hole gnawed in the pupa case.

The Capsid bug is *Campylomma livida*, Reut. (Pl. XX, fig. 13) which is a small green bug found in all its stages on the crumpled indigo tops or rather hidden among the crumpled

leaves. The nymphs move about very quickly and the adults too, are very active and fly away when disturbed. The bug is found thrusting its beak into and among the crumpled leaves to get at the young nymphs which always live hidden in such positions and are thus safe from other enemies.

The spiders prey upon the "Psylla" adults only. Three species were definitely observed to spin webs across the affected indigo plants. The adults were caught in the usual way on the webs. Probably all spiders which live in the indigo fields will be found to prey upon "Psylla," as a matter of course.

Another black spider has been found catching and eating adults. It does not spin a web and mimicks the black ant, *Camponotus compressus* which attends the "Psylla", both nymphs and adults. It moves about briskly on the plants in search of the prey. Occasionally it rests for some time on a leaflet and again begins to reconnoitre quickly.

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